

High-performance serving of large-scale OpenDRIVE datasets using standardized GIS technology

6th Symposium Driving Simulation, 2020-11-05, Virtual Event

Michael Scholz



Knowledge for Tomorrow



German Aerospace Center (DLR)

Institute of Transportation Systems

A large, curved view of the Earth from space, showing the blue atmosphere, white clouds, and green and brown landmasses. The Earth is positioned in the lower right quadrant of the slide, curving upwards from the bottom edge.

Knowledge for Tomorrow

German Aerospace Center



Research institutes

- Aeronautics
- Space
- Energy
- Transportation
- Security
- Digitalisation

Space administration

Project management agency



Institute of Transportation Systems

Key facts

- In Berlin and Brunswick
- Around 220 employees

Research fields

- Automotive
- Railway systems
- Traffic management
- Multi-modal and public transport

Area of work

- Fundamental research
- Conception and strategy development
- Prototyping



Our research infrastructure ...



... and our Testbed of Lower Saxony



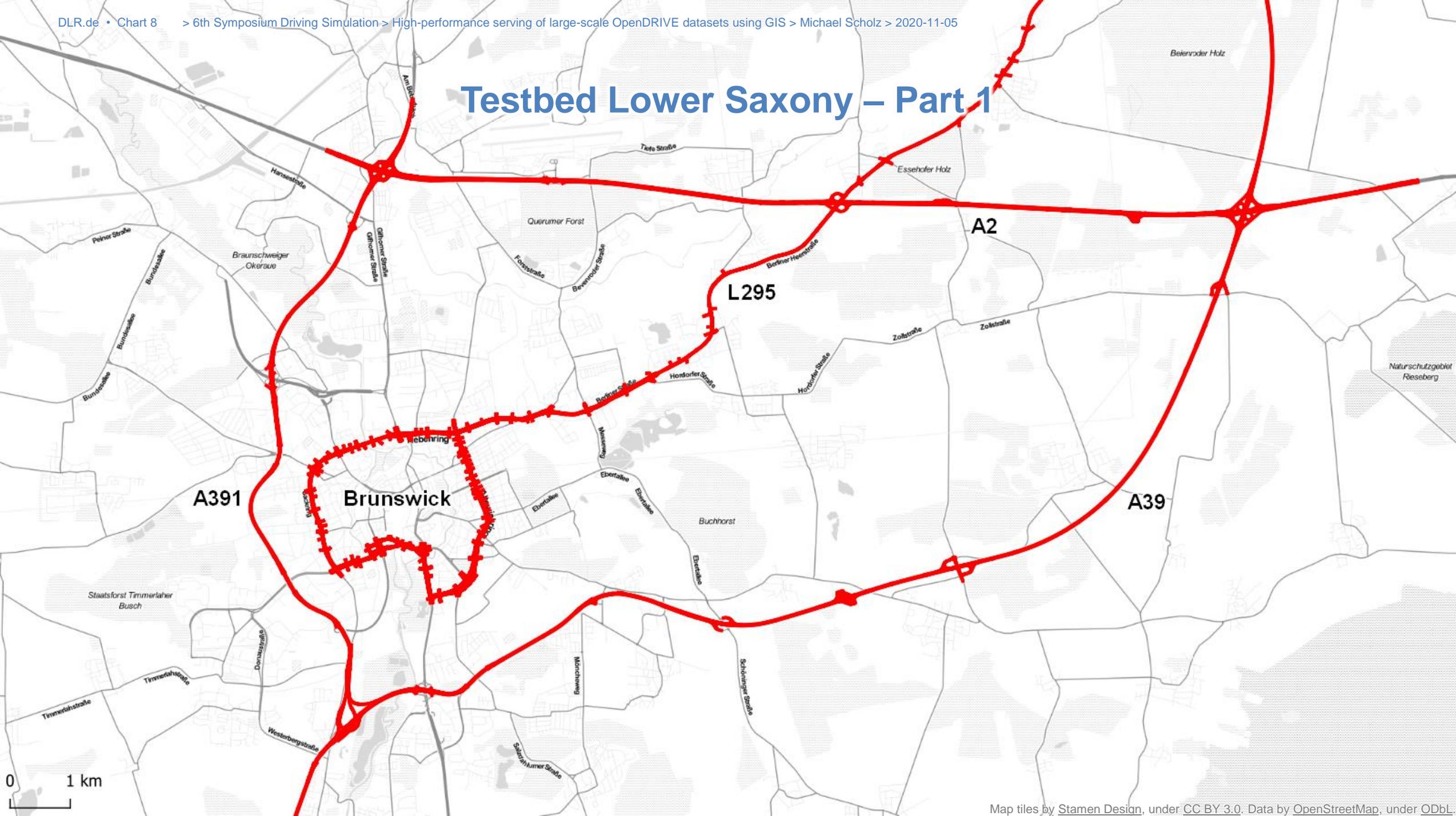
Challenges



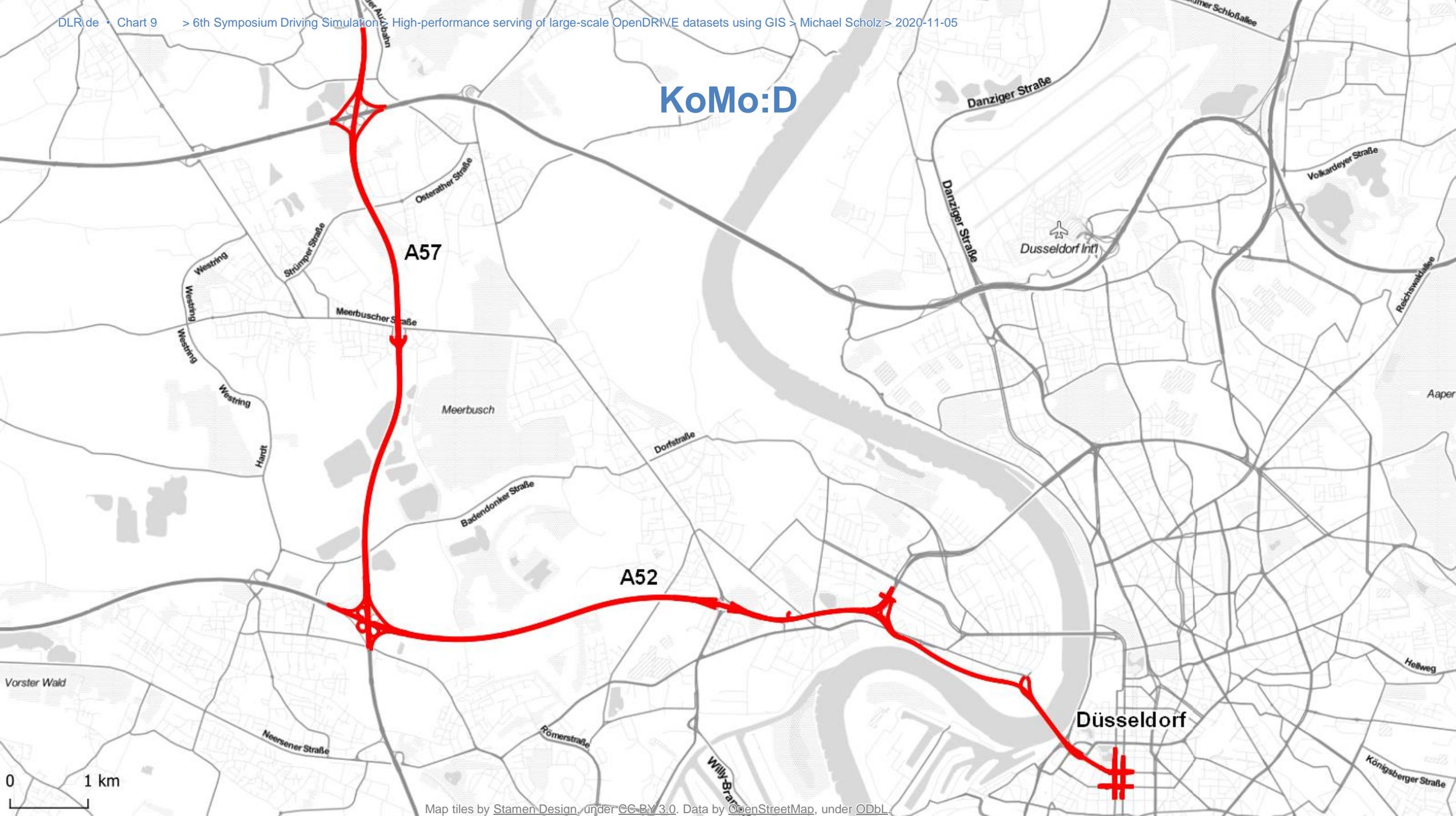
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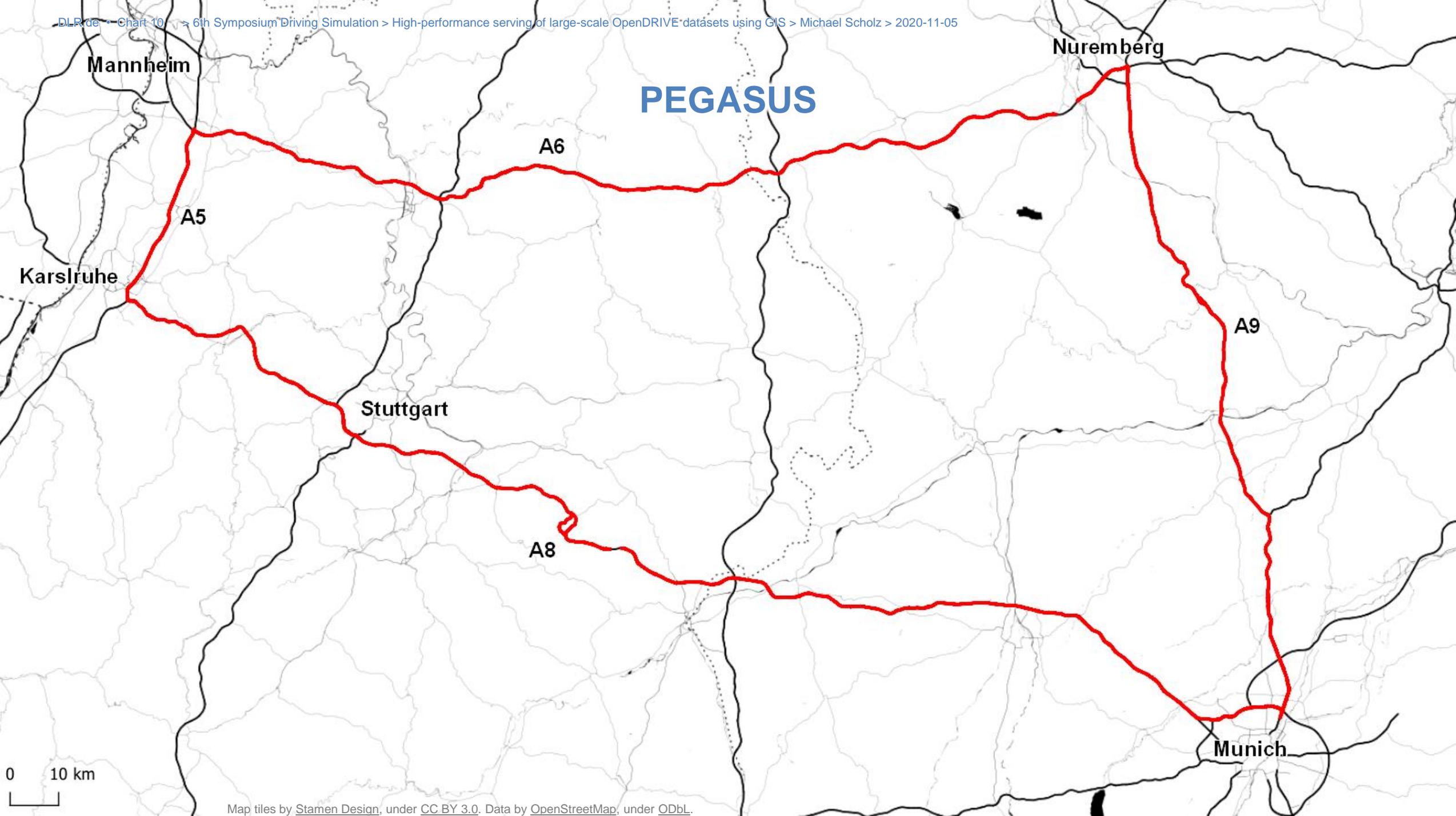


Testbed Lower Saxony – Part 1



KoMo:D





PEGASUS

Mannheim

Nuremberg

Karlsruhe

Stuttgart

Munich

A5

A6

A9

A8

0 10 km

What is desirable?

- Consistent **management** of such *heterogeneous* datasets
- Fast **access** and data browsing for different users
- Simple **interface/API**
- Easy **snippet extraction** from whole datasets



OpenDRIVE over time

Initial scope of application

- Fast prototyping of simulation tracks
→ Artificial/imaginary test data
- Restricted (small) spatial extent
- High modelling detail with visual properties
→ 3D rendering
- Simple, continuous geometry definition
→ Smooth road course
- Real-time processing capability

Current and future trends

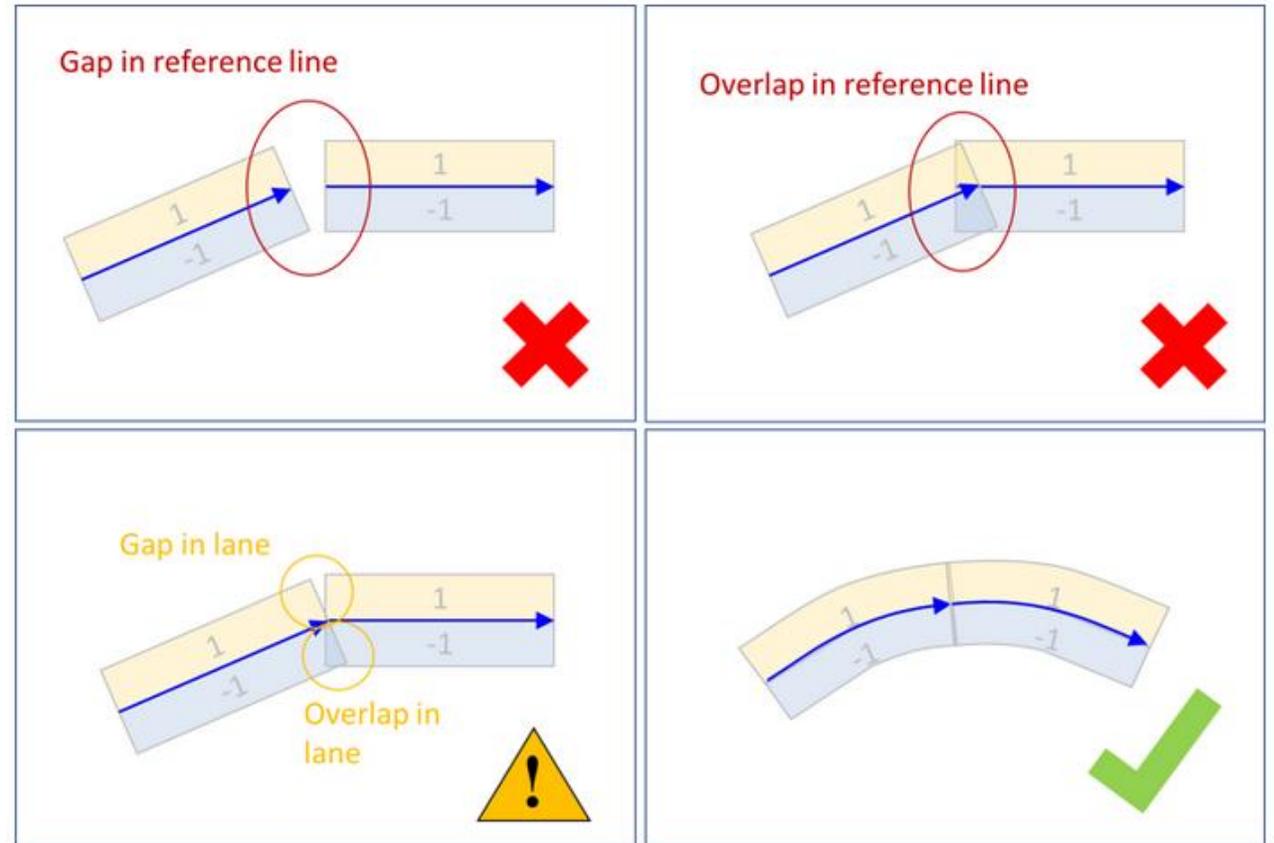
- Real-world data
 - From motorways over
 - inner cities to
 - multi-level parking decks
- Data updates and network merging
- Increasing spatial extents
- “From simulation into the car”
→ Electronic horizon, rejection of styling elements
- Linkage to supplementary environmental data



OpenDRIVE is bad for

Extracting/editing

- Because you need tools which are
 - commercial (money, money, money),
 - complicated,
 - inflexible,
 - ugly.
- Because there is no server-based solution “as a service”



OpenDRIVE is bad for

Data exchange

- Because of strong data model hierarchy and element cross-references

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

```
<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"/>
```

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

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



OpenDRIVE is bad for

Data exchange

- Because of strong data model hierarchy and element cross-references
- Because small data snippets quickly result in millions of lines of text



```
18 </geometry>
19 <geometry s="3.115631124120e+02" :
    "4.333214085751e+00" length="2.07
20 <paramPoly3 aU="-0.000000000000000
    "-1.522623174711e-09" aV="0.0000
    dV="1.093841523093e-08" pRange=
21 </geometry>
22 <geometry s="5.192728943920e+02" :
    "4.312933712501e+00" length="1.03
23 <paramPoly3 aU="-0.000000000000000
    "-1.086489461279e-09" aV="0.0000

eXtensible Markup Language file length : 322.530.389 lines : 2.497.443
```



Subset extraction is not trivial



Solving “the problem” in three steps

1. Make OpenDRIVE data GIS-able
2. Deploy GIS data in spatial database
3. Publish as RESTful web service



Knowledge for Tomorrow



GIS? Why?

- Well-established **standards** around for 15+ years (OGC)
- A super-huge **community** of which all automotive guys can just dream about
- They know how to **handle huge data**
- Broad tool support, also **for free** (open source software)
- Some components offer **standardised services**
- Native workflow with cadastral data, CAD, Road2Simulation, Lanelet/2, ...



GIS? Why?

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“Don’t re-invent the wheel”



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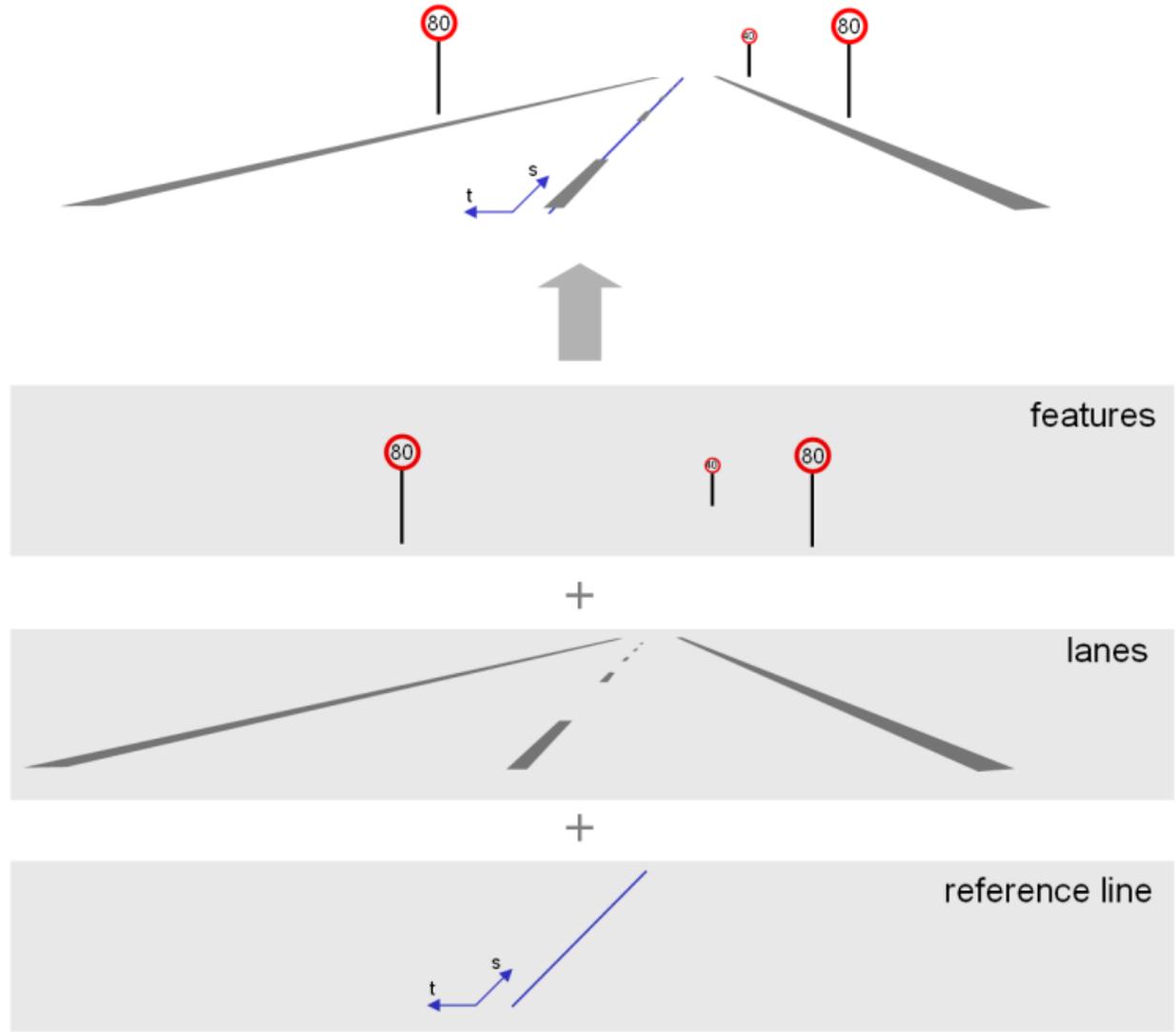
Knowledge for Tomorrow



Make OpenDRIVE data GIS-able

Geometry basics

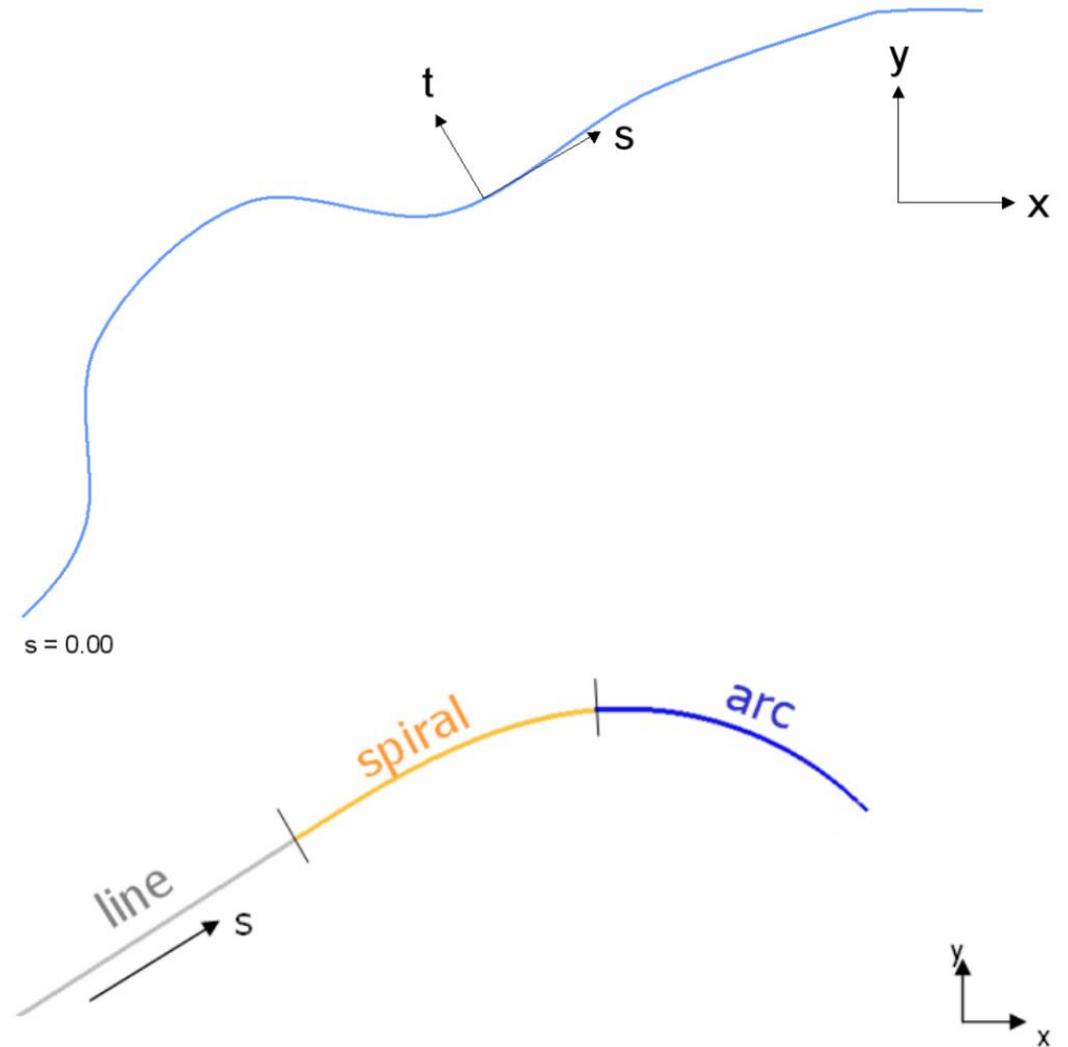
- Elements refer to an imaginary reference line



Make OpenDRIVE data GIS-able

Geometry basics

- Elements refer to an imaginary reference line
- Road topography (3D) and topology
 - continuous geometry definition



Make OpenDRIVE data GIS-able

Geometry basics: discrete anchor points

```
<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>
```



Make OpenDRIVE data GIS-able

Geometry basics: continuous geometry evolution

```
<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>
```



Make OpenDRIVE data GIS-able

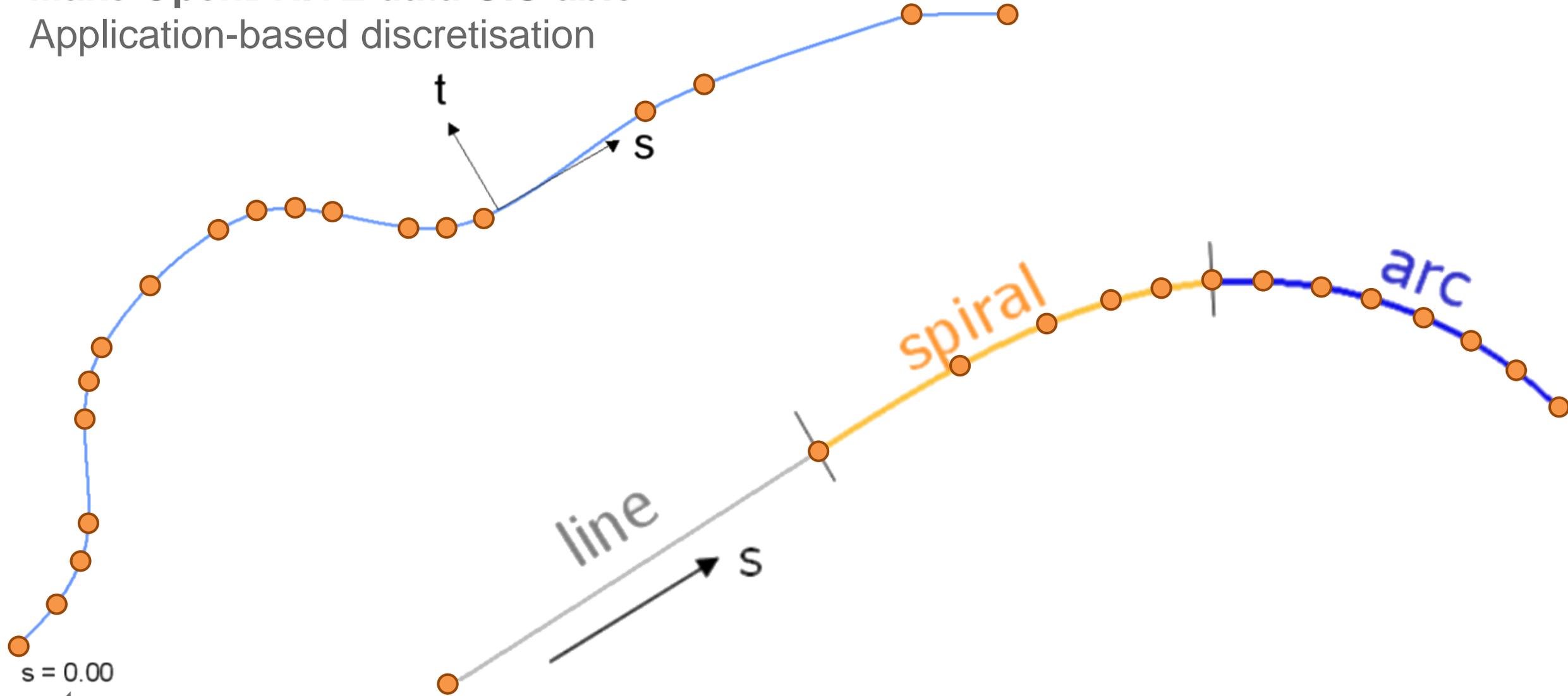
Application-based discretisation (sampling)

“Everyone is doing this!”



Make OpenDRIVE data GIS-able

Application-based discretisation



Make OpenDRIVE data GIS-able

OGC Simple Feature primitives

OGC
Making location count.

About ▾ Standards ▾ Innovation ▾ News & Events ▾ Membership ▾ Resources ▾

Simple Feature Access - Part 1: Common Architecture

1) Downloads
2) Related News

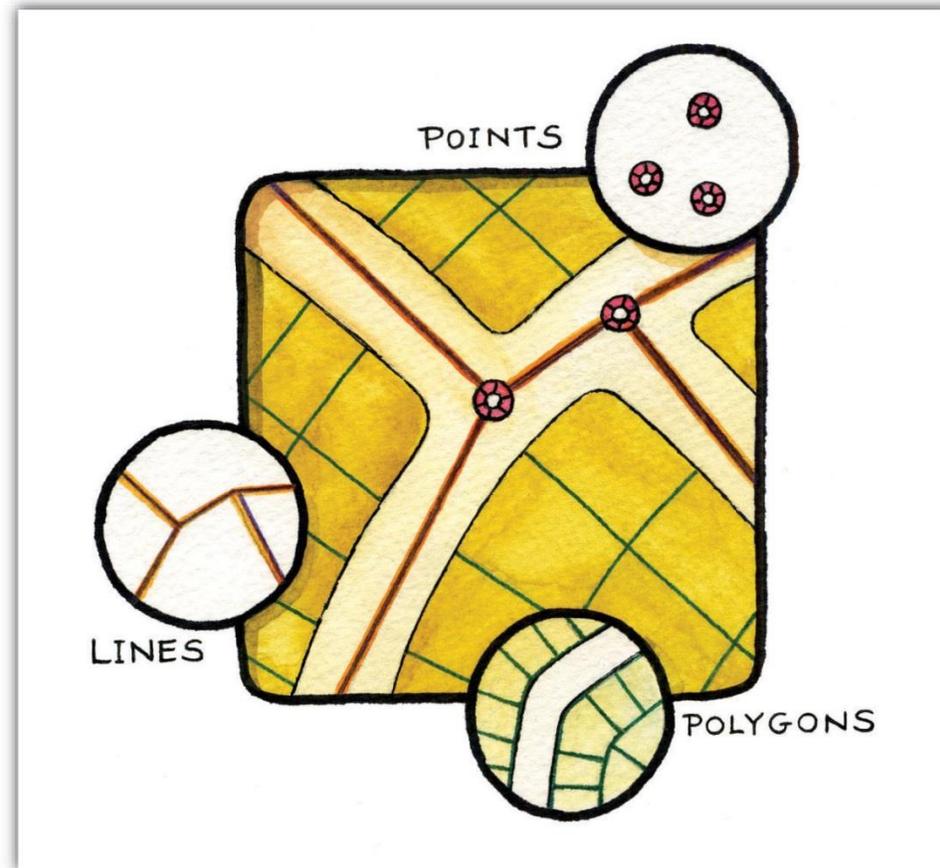
1) Downloads

Version	Document Title (click to download)	Document #	Type
1.2.1	OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture	06-103r4	IS
1.2.0	OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture	06-103r3	D-IS
1.1.0	OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture	05-126	D-IS

- OGC® Standards
 - 3D Tiles
 - 3dP
 - ARML2.0
 - Cat: ebRIM App Profile: Earth Observation Products
 - Catalogue Service
 - CDB
 - CityGML
 - Coordinate Transformation
 - Filter Encoding
 - GML in JPEG 2000
 - GeoAPI
 - GeoPackage
 - GeoSciML
 - GeoSPARQL
 - Geography Markup Language
 - GeoRSS
 - Geospatial eXtensible Access Control Markup Language (GeoXACML)
 - Geospatial User Feedback (GUF)
 - GeoTiff

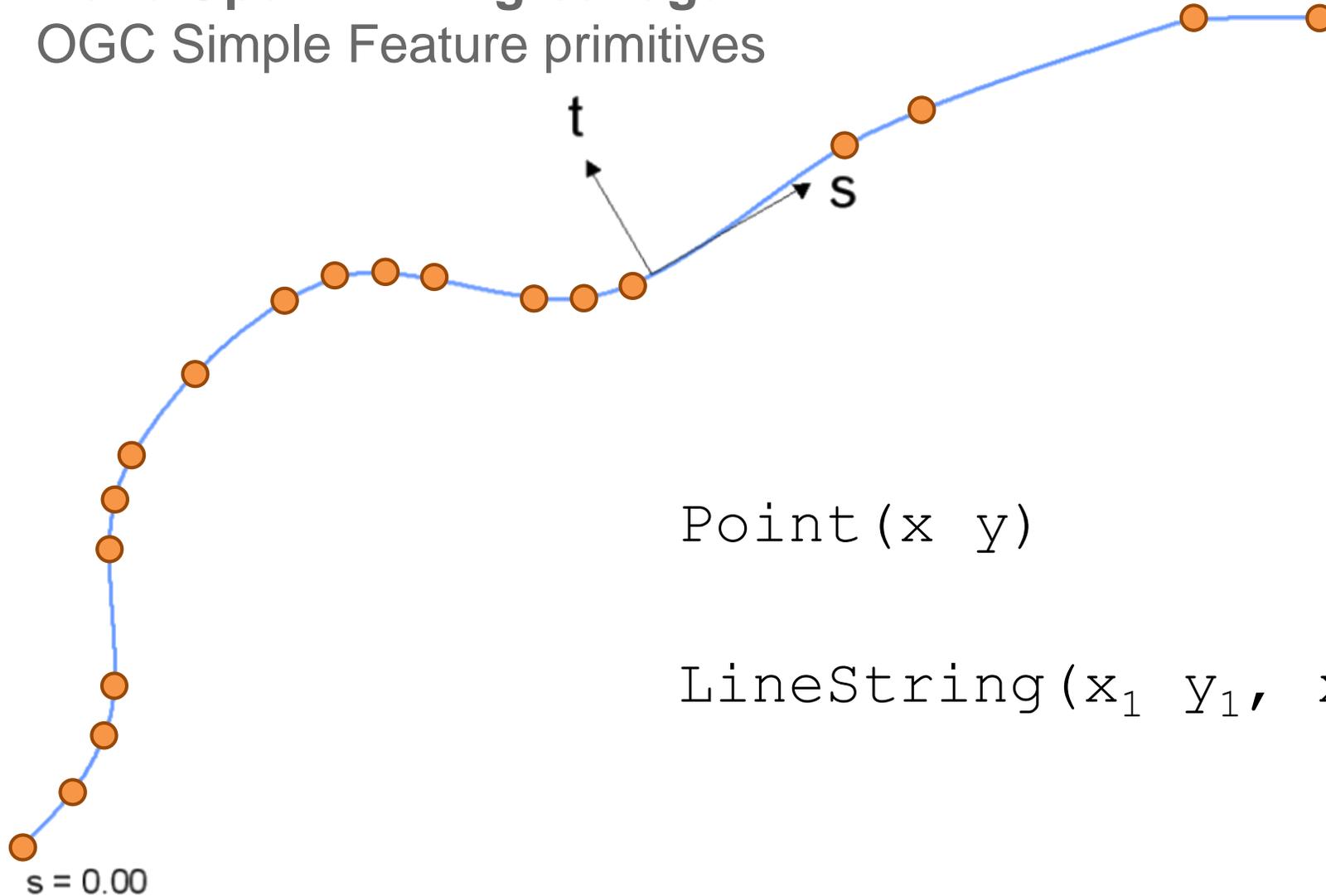
Make OpenDRIVE data GIS-able

OGC Simple Feature primitives



Make OpenDRIVE great again

OGC Simple Feature primitives



Point (x y)

LineString (x₁ y₁, x₂ y₂, ..., x_n y_n)



Make OpenDRIVE data GIS-able

Translation into Simple Feature model



```

<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>

```

```

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

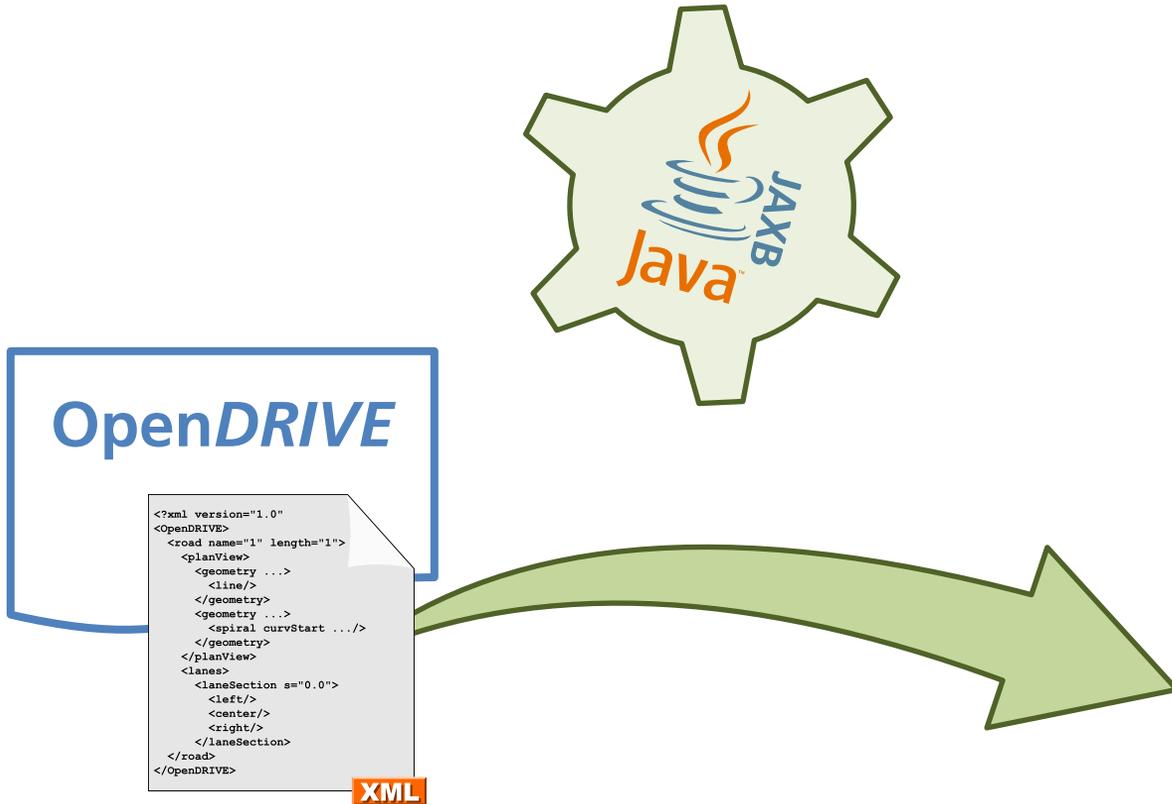
LineString(
  604935.03 5792856.5285,
  604754.39 5792810.73, ...)

```



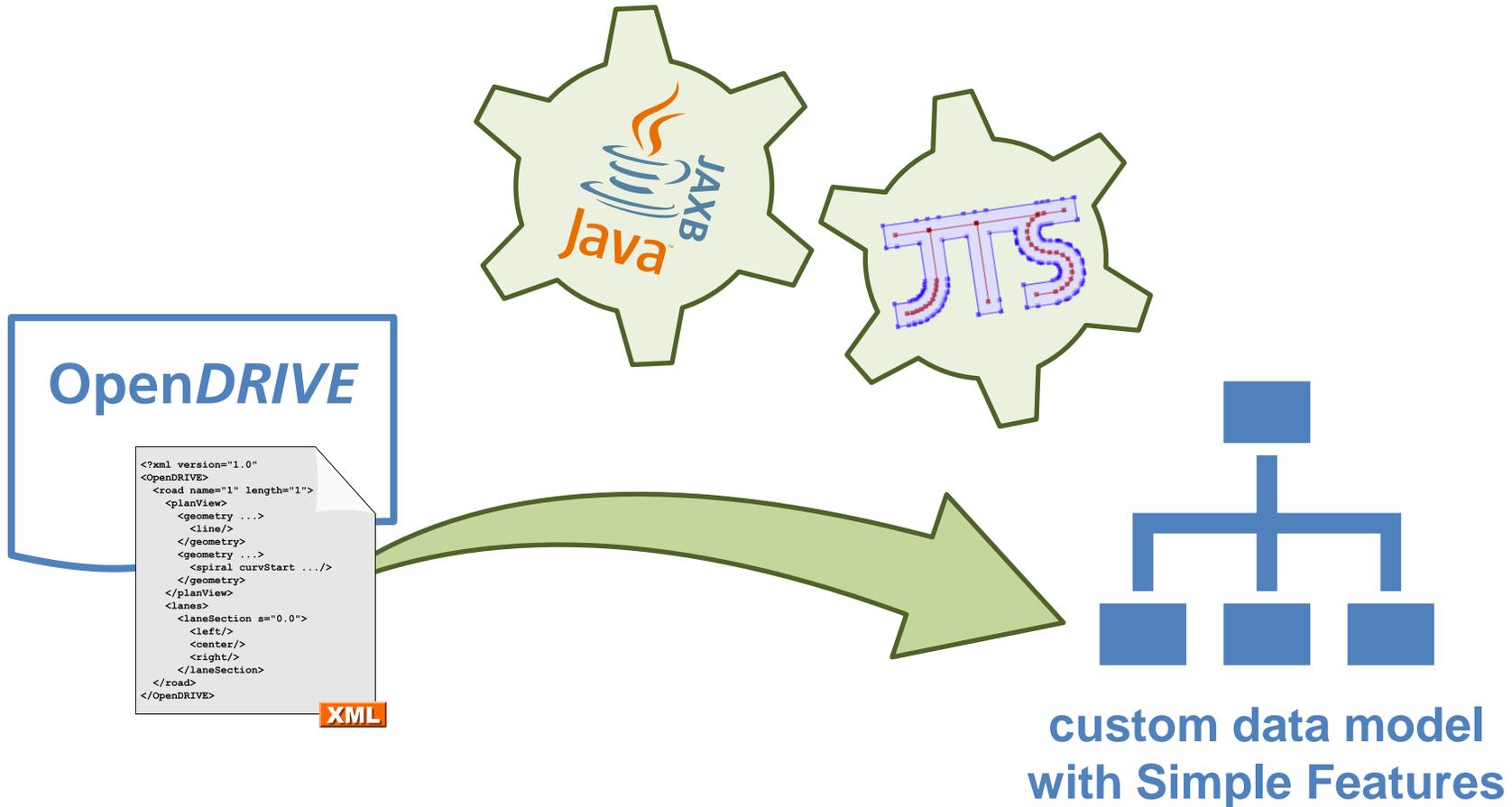
Make OpenDRIVE data GIS-able

Data binding to Java



Make OpenDRIVE data GIS-able

Geometry discretisation into Simple Feature model



Solving “the problem” in three steps

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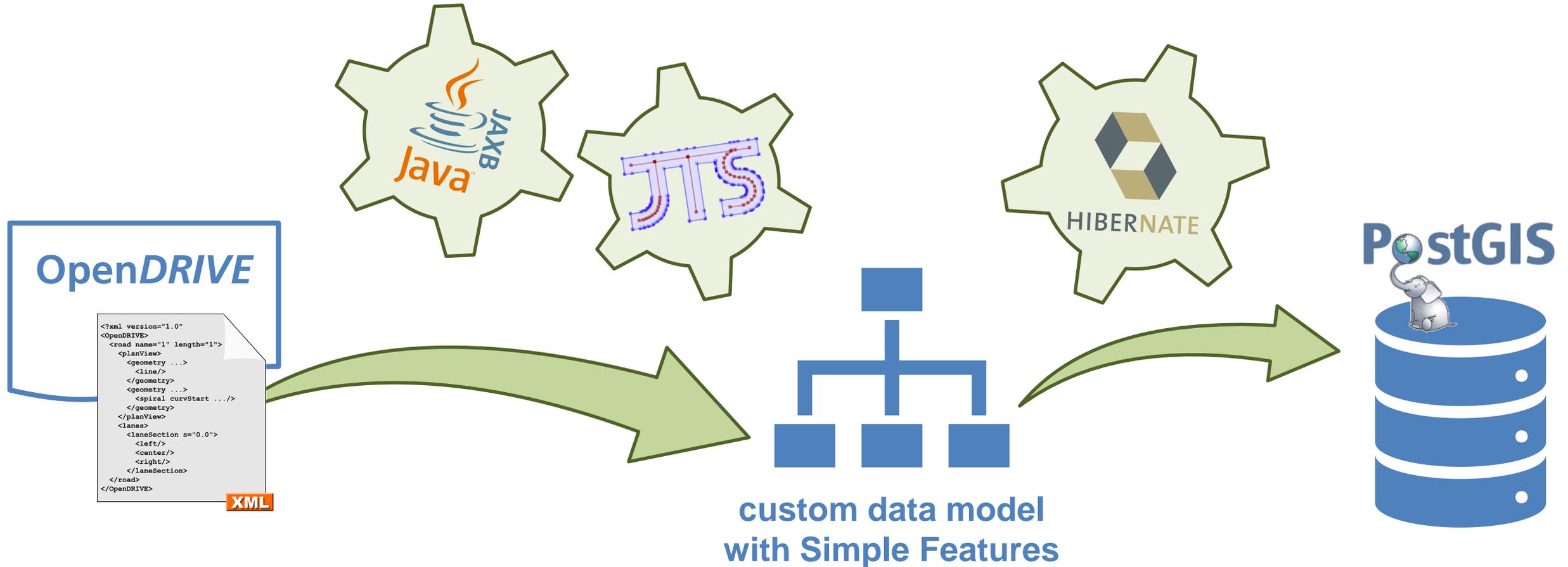


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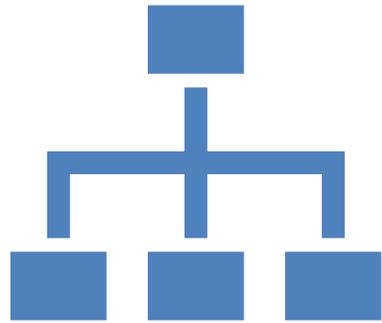
Deploy GIS data in spatial database

Persisting through JPA with Hibernate Spatial



Deploy GIS data in spatial database

Custom data model



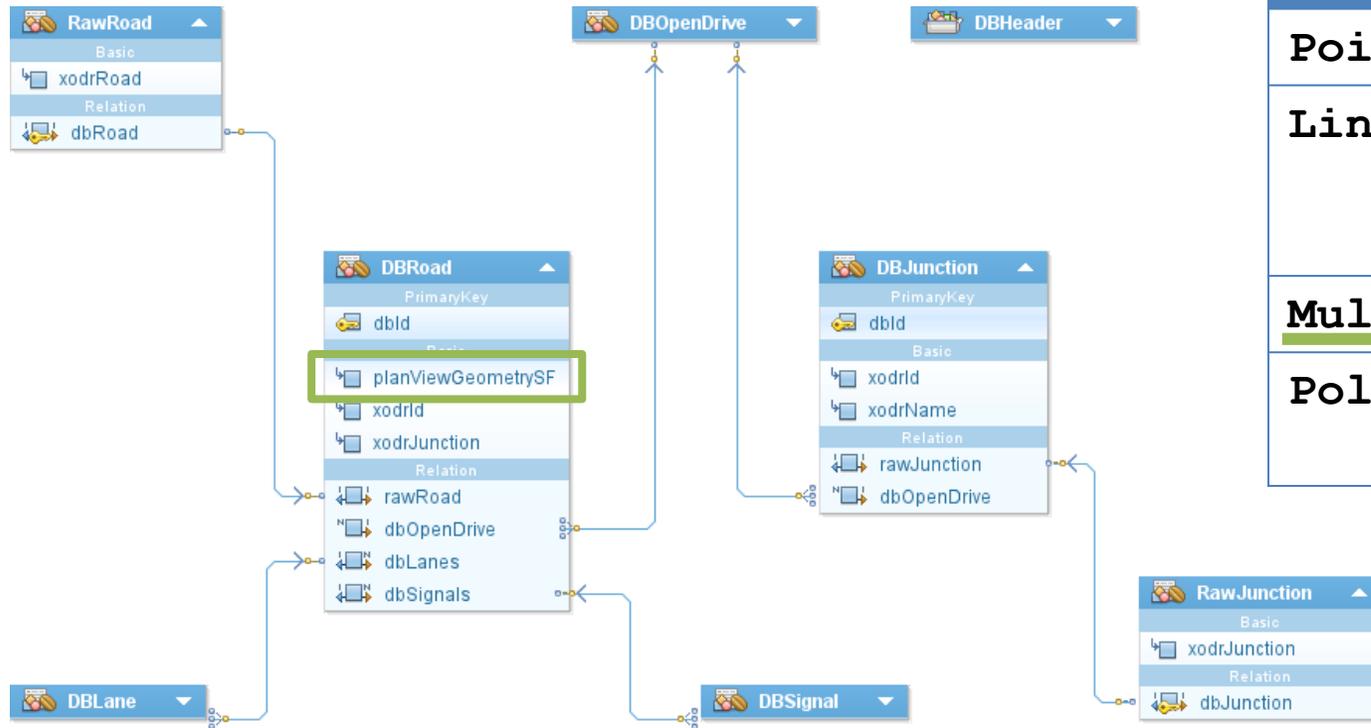
custom data model
with Simple Features

Simple Feature type	OpenDRIVE element
Point	<code><signal></code>
LineString	driving <code><lane></code> boundary, <code><roadMark></code> , linear <code><object></code> (e.g. guardrail)
MultiLineString	road reference line <code><planView></code>
Polygon	driving <code><lane></code> , <code><parkingSpace></code>



Deploy GIS data in spatial database

Custom data model

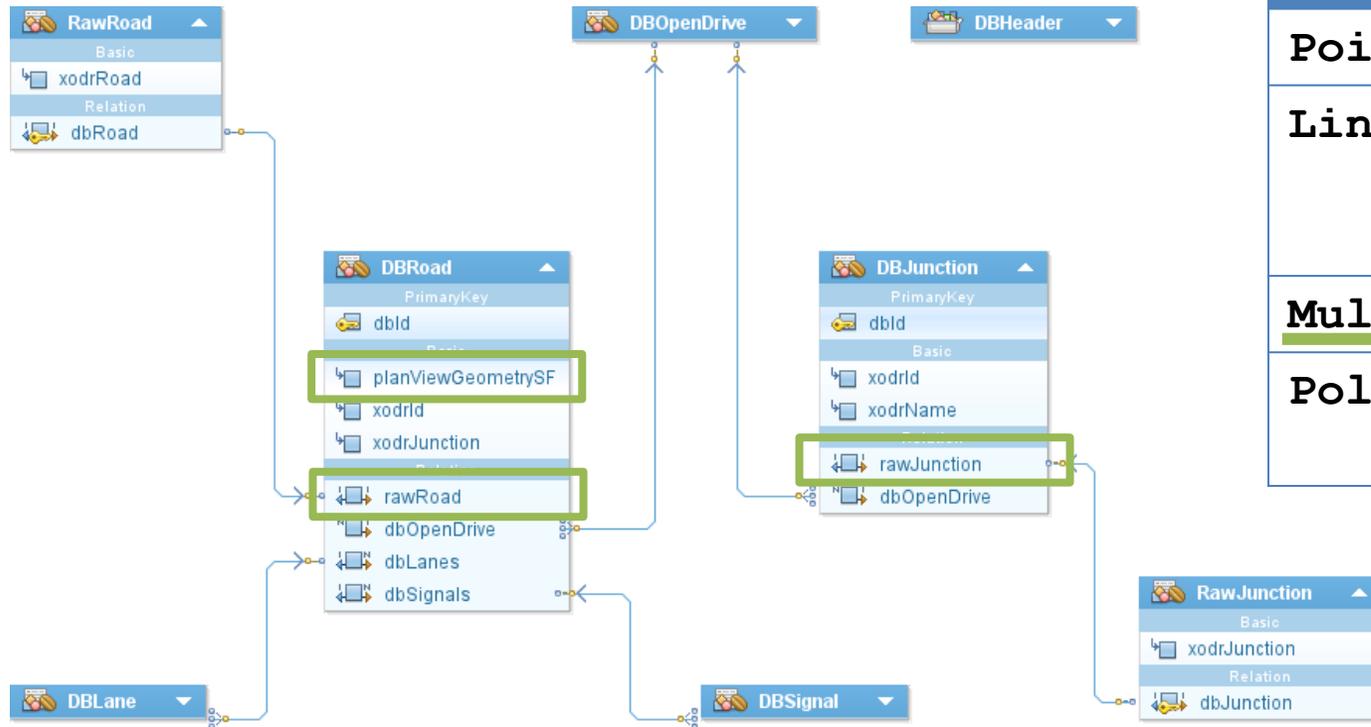


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Deploy GIS data in spatial database

Custom data model



Simple Feature type	OpenDRIVE element
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MultiLineString	road reference line <planView>
Polygon	driving <lane>, <parkingSpace>

Additional raw XML elements “attached”

- <road>
- <junction>



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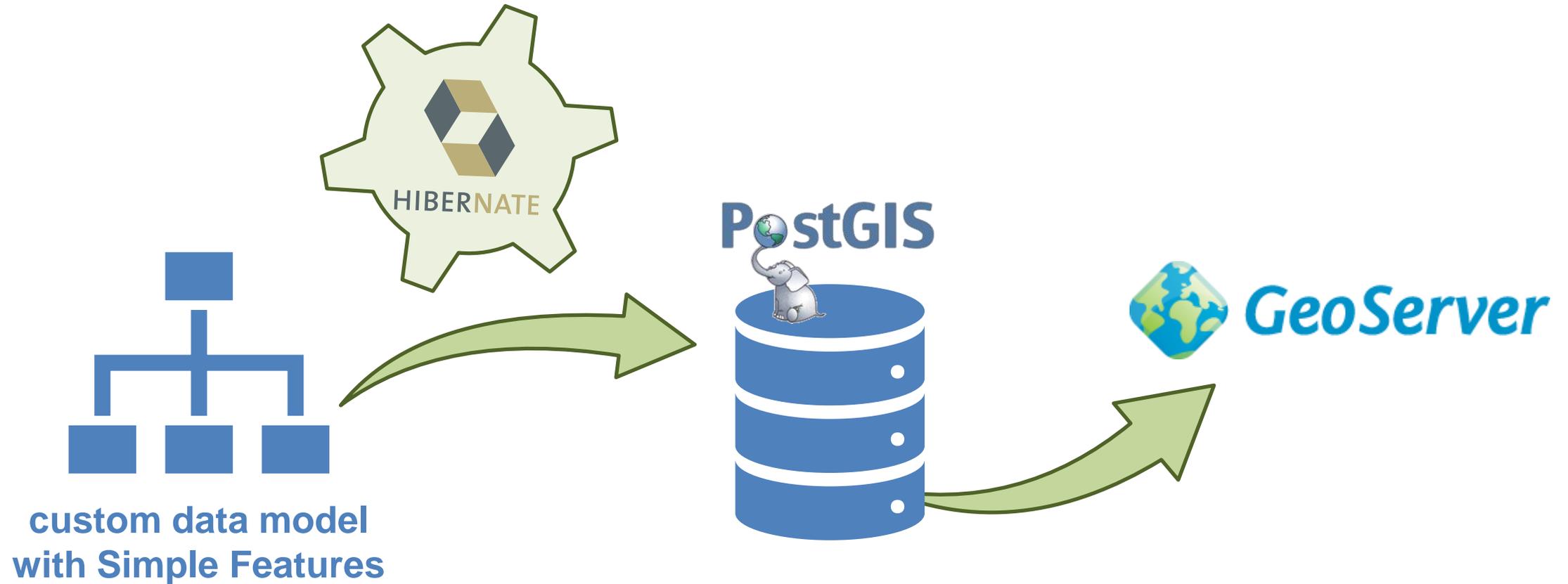


Knowledge for Tomorrow

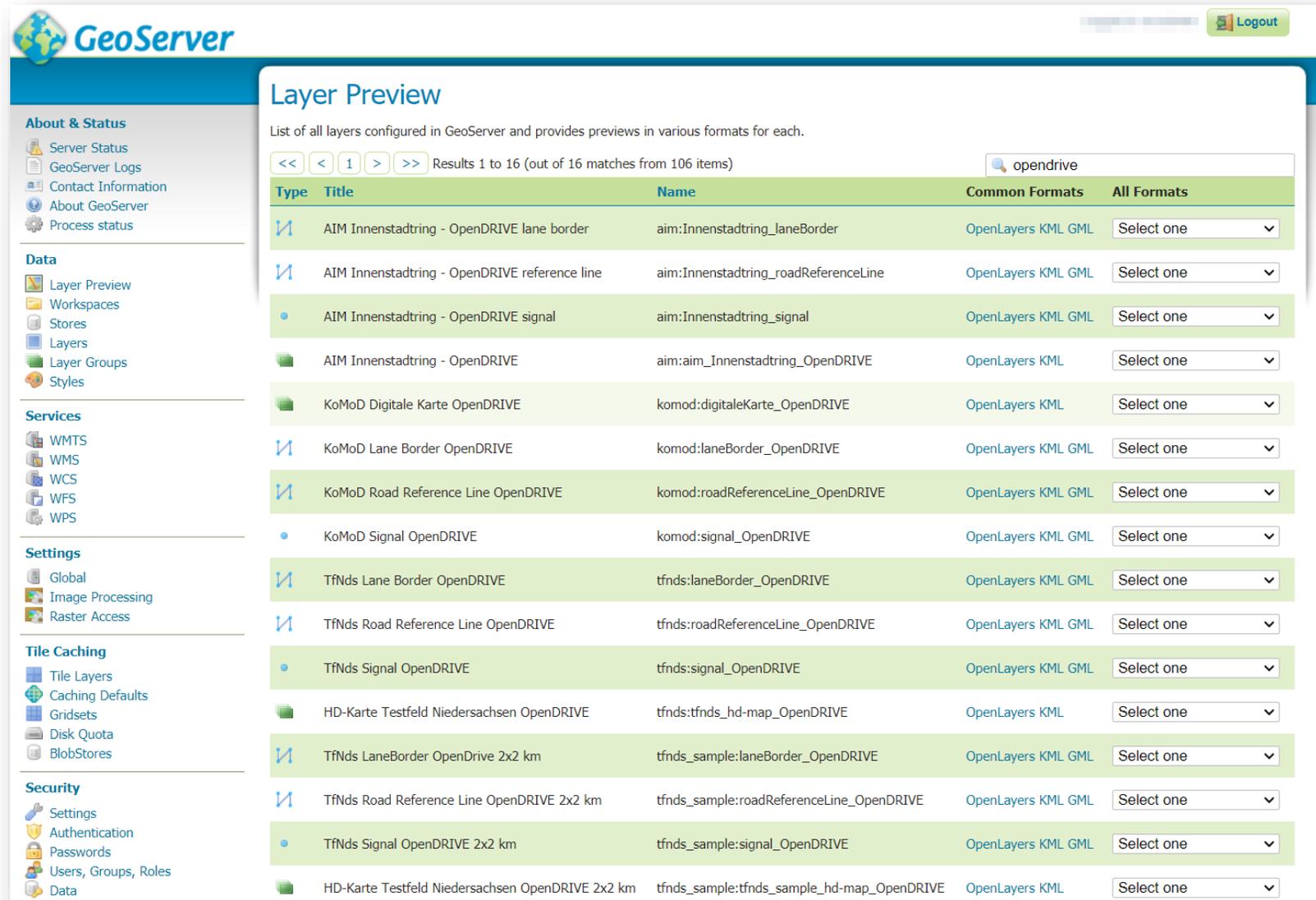


Publish as RESTful web service

Directly from database through GeoServer



Publish as RESTful web service



The screenshot shows the GeoServer web interface. On the left is a navigation sidebar with categories: About & Status, Data, Services, Settings, Tile Caching, and Security. The main content area is titled 'Layer Preview' and displays a table of layers. A search bar at the top right of the table contains the text 'opendrive'. The table has five columns: Type, Title, Name, Common Formats, and All Formats. The table lists 16 layers, each with a preview icon, a title, a name, and available formats. A large green arrow on the left side of the slide points from the text 'Publish as RESTful web service' towards the 'Layer Preview' table.

Type	Title	Name	Common Formats	All Formats
	AIM Innenstadttring - OpenDRIVE lane border	aim:Innenstadtring_laneBorder	OpenLayers KML GML	Select one
	AIM Innenstadttring - OpenDRIVE reference line	aim:Innenstadtring_roadReferenceLine	OpenLayers KML GML	Select one
	AIM Innenstadttring - OpenDRIVE signal	aim:Innenstadtring_signal	OpenLayers KML GML	Select one
	AIM Innenstadttring - OpenDRIVE	aim:aim_Innenstadtring_OpenDRIVE	OpenLayers KML	Select one
	KoMoD Digitale Karte OpenDRIVE	komod:digitaleKarte_OpenDRIVE	OpenLayers KML	Select one
	KoMoD Lane Border OpenDRIVE	komod:laneBorder_OpenDRIVE	OpenLayers KML GML	Select one
	KoMoD Road Reference Line OpenDRIVE	komod:roadReferenceLine_OpenDRIVE	OpenLayers KML GML	Select one
	KoMoD Signal OpenDRIVE	komod:signal_OpenDRIVE	OpenLayers KML GML	Select one
	TfNds Lane Border OpenDRIVE	tfnds:laneBorder_OpenDRIVE	OpenLayers KML GML	Select one
	TfNds Road Reference Line OpenDRIVE	tfnds:roadReferenceLine_OpenDRIVE	OpenLayers KML GML	Select one
	TfNds Signal OpenDRIVE	tfnds:signal_OpenDRIVE	OpenLayers KML GML	Select one
	HD-Karte Testfeld Niedersachsen OpenDRIVE	tfnds:tfnds_hd-map_OpenDRIVE	OpenLayers KML	Select one
	TfNds LaneBorder OpenDrive 2x2 km	tfnds_sample:laneBorder_OpenDRIVE	OpenLayers KML GML	Select one
	TfNds Road Reference Line OpenDRIVE 2x2 km	tfnds_sample:roadReferenceLine_OpenDRIVE	OpenLayers KML GML	Select one
	TfNds Signal OpenDRIVE 2x2 km	tfnds_sample:signal_OpenDRIVE	OpenLayers KML GML	Select one
	HD-Karte Testfeld Niedersachsen OpenDRIVE 2x2 km	tfnds_sample:tfnds_sample_hd-map_OpenDRIVE	OpenLayers KML	Select one

Publish as RESTful web service

The power of GeoServer

- Detailed **user management**
- Fine-grained **data security**/access policies
- OGC-standardised **REST API** (this “web thing”)
 - Web Map Service (WMS)
 - Web Feature Service (WFS)
 - Web Processing Service (WPS)
- Data output as image, KML, GML, GeoJSON, CSV, Shapefile, etc.
- Easy **snippet extraction** through custom **extension**
- Benefiting **spatial indices** on data → “fast like hell”
- Scalability
- Integration into most GIS tools
- Bla, bla, bla ...



Live demo

OpenDRIVE through GeoServer

OpenDRIVE in QGIS

OpenDRIVE subset/snippet extraction queries



Knowledge for Tomorrow



Conclusion: “Don’t re-invent the wheel”

- Geometry discretization should be based on OGC Simple Features
- Benefit from well-established tools in GIS domain:
 - Free/open frameworks for Java, C++, Python, ... and web development
 - Super-easy ad hoc combination with arbitrary geo-data
 - Direct conversion into 100+ other formats: KML, GML, GeoJSON, CSV, Shapefile, SQLite, XLSX, ...
→ GDAL: “One library to rule them all”
 - Standardized web service interfaces already implemented (OGC WMS, WFS, ...)

This ecosystem enables fast, large-scale serving of OpenDRIVE



STADTBELEUCHTUNG 902945

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

<https://youtu.be/diEnlUT6HmA>

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Internet www.DLR.de/ts/en

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)

Fahrbahnmarkierung 85736A

Source: Mobile Mapping x: 605 160.78 r: 15
y: 577 285.07 (UTM)

GEBÄUDE 7267839

Source: Geoinformation Braunschweig x: 605 153.39 r: 0
y: 577 302.98 (UTM)

GELÄNDEMDELL

Source: Geoinformation Braunschweig