ASAM OpenDRIVE Webinar
Part 1

Nicco Dillmann
ASAM e.V.

14th October 2020
ASAM Webinar

ASAM Association for Standardization of Automation and Measuring Systems

Announcements upcoming events

- ASAM Regional Meeting North America – Online Meeting

  Day: Oct 29, 2020

  Time: 10:00 am - 1:15 pm (EDT) | 7:00 am - 10:15 am (PDT)

  Topics: ASAM OpenX projects | SOVD (Service-Oriented Vehicle Diagnostics) | Amazon Web Services: Activites in ADAS / AD

  Agenda -> Registration ->

- 1st ASAM Regional Meeting China – SAVE THE DATE

  Day: Nov 26 – 27, 2020

  Time: Nov 26: 15:00 - 18:00 (CST) | Nov 27: 9:00 - 17:00 (CST)

  Registration will open soon!

- ASAM General Assembly 2021 (Online) – SAVE THE DATE

  Day: Mar 24, 2021

  Time: 09:00 – 12:00 CET

⇒ Sign up for the ASAM newsletter to be informed about upcoming webinars, projects and events
www.asam.net/newsletter

Agenda

2:00 pm – 2:40 pm (CET)	OpenDRIVE Webinar Part 1
2:40 pm – 2:50 pm (CET)	Q&A Part 1
2:50 pm – 3:00 pm (CET)	Coffee Break
3:00 pm – 3:30 pm (CET)	OpenDRIVE Webinar Part 2
3:30 pm – 3:45 pm (CET)	Q&A Part 2

OpenX Overview

The OpenX portfolio so far…

OpenSCENARIO
- Dynamic scene description

OpenDRIVE
- Static road network

OpenCRG
- Detailed Road surface description

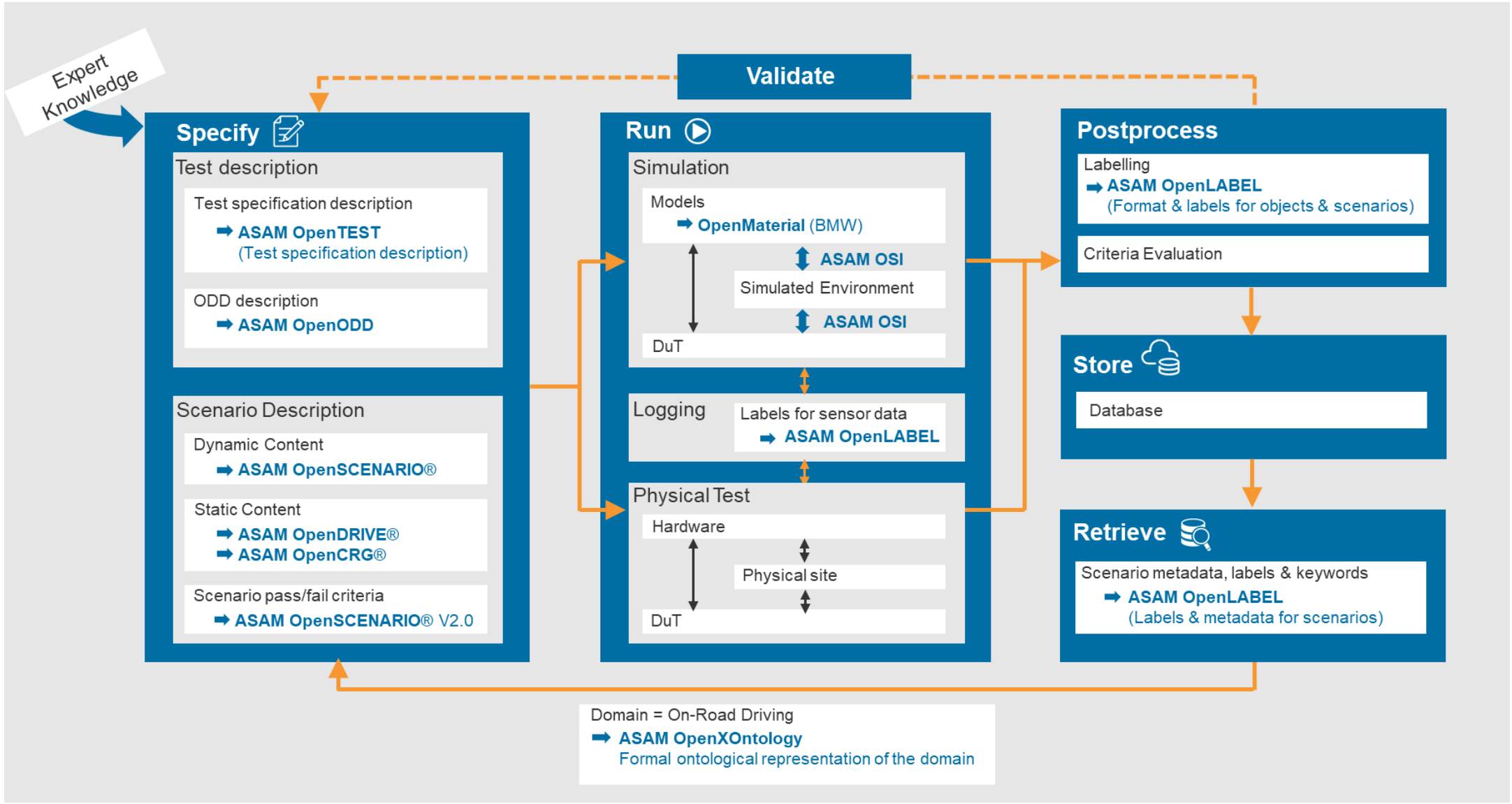
Open Simulation Interface
- Interface for environmental perception of AD functions

OpenLABEL
- Labels and labelling format for objects & scenarios

OpenODD
- ODD definition format

OpenXOntology
- Extendable domain ontology for on road driving

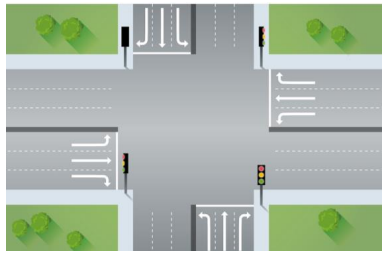
Scenario-Based Testing (SBT) with OpenX



ASAM

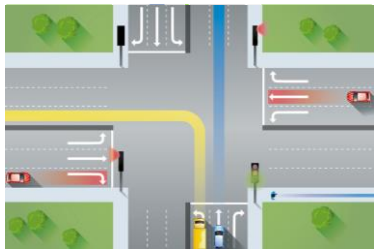
Overview: OpenDRIVE, OpenSCENARIO, OpenCRG

Static road network description



ASAM OpenDRIVE®

dynamic scenario description



ASAM OpenSCENARIO®

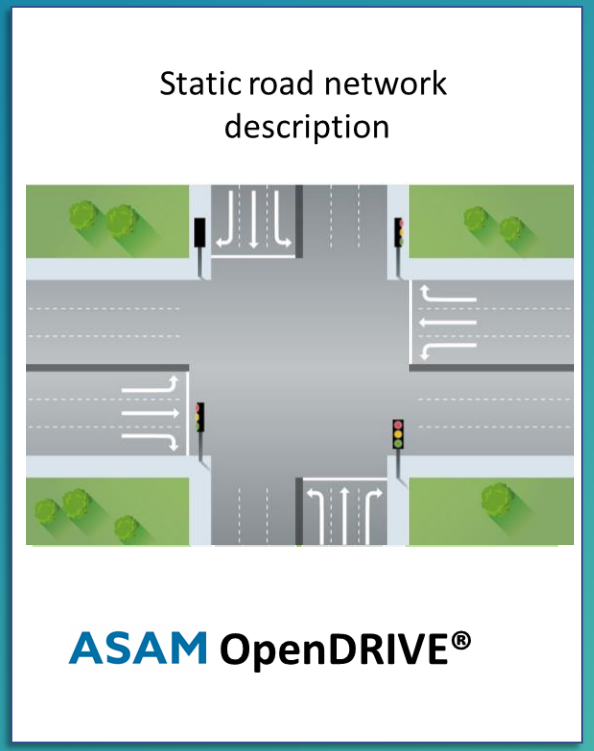
Scenario description, with dynamic and static content

[0..*]

Static road surface description

ASAM OpenCRG®

ASAM OpenDRIVE

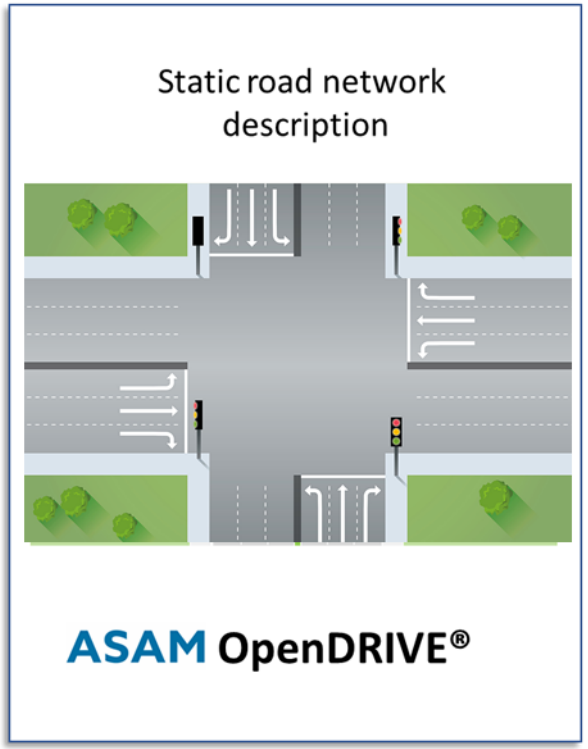


What is it for, strength and weaknesses

OpenDRIVE: Describes the static road network and is being referenced by OpenSCENARIO. OpenDRIVE also describes the static Objects around the street network, such as signals, traffic islands, infrastructure.

Strength:

- Precise semantic description of a road network:
  - Geometry
  - Lanes
  - Roadmarks
  - Traffic Infrastructure
  - …
- Designed be interpreted by simulations
- Provides an exchangeable format



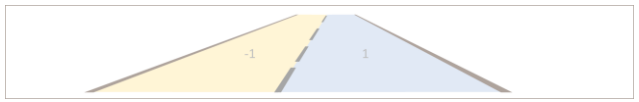
Weaknesses:

- Only rough environmental modelling capabilities
- No visual information
- Junction modelling is very complex

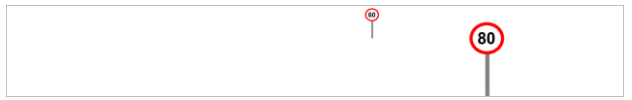
ASAM OpenDRIVE: Hierachy

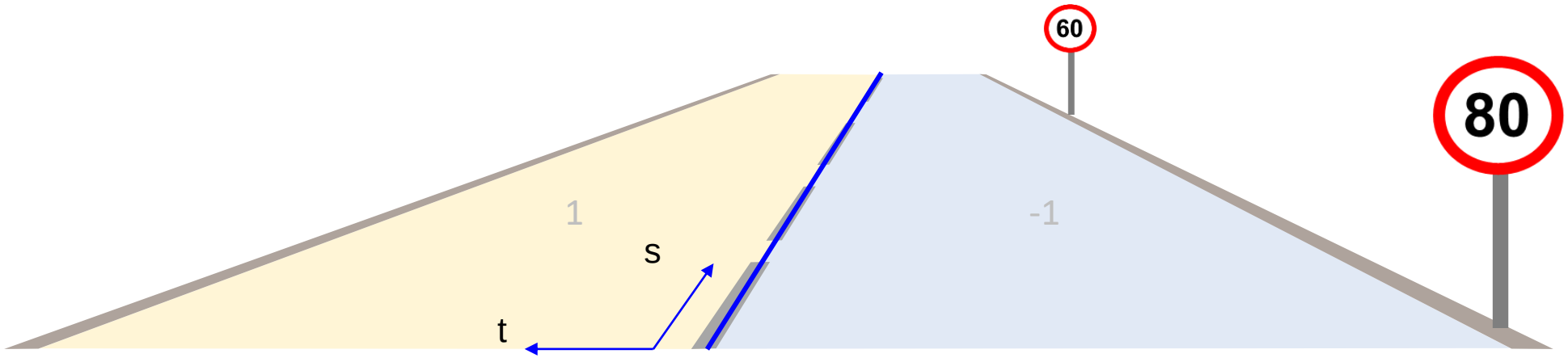
reference line

lanes



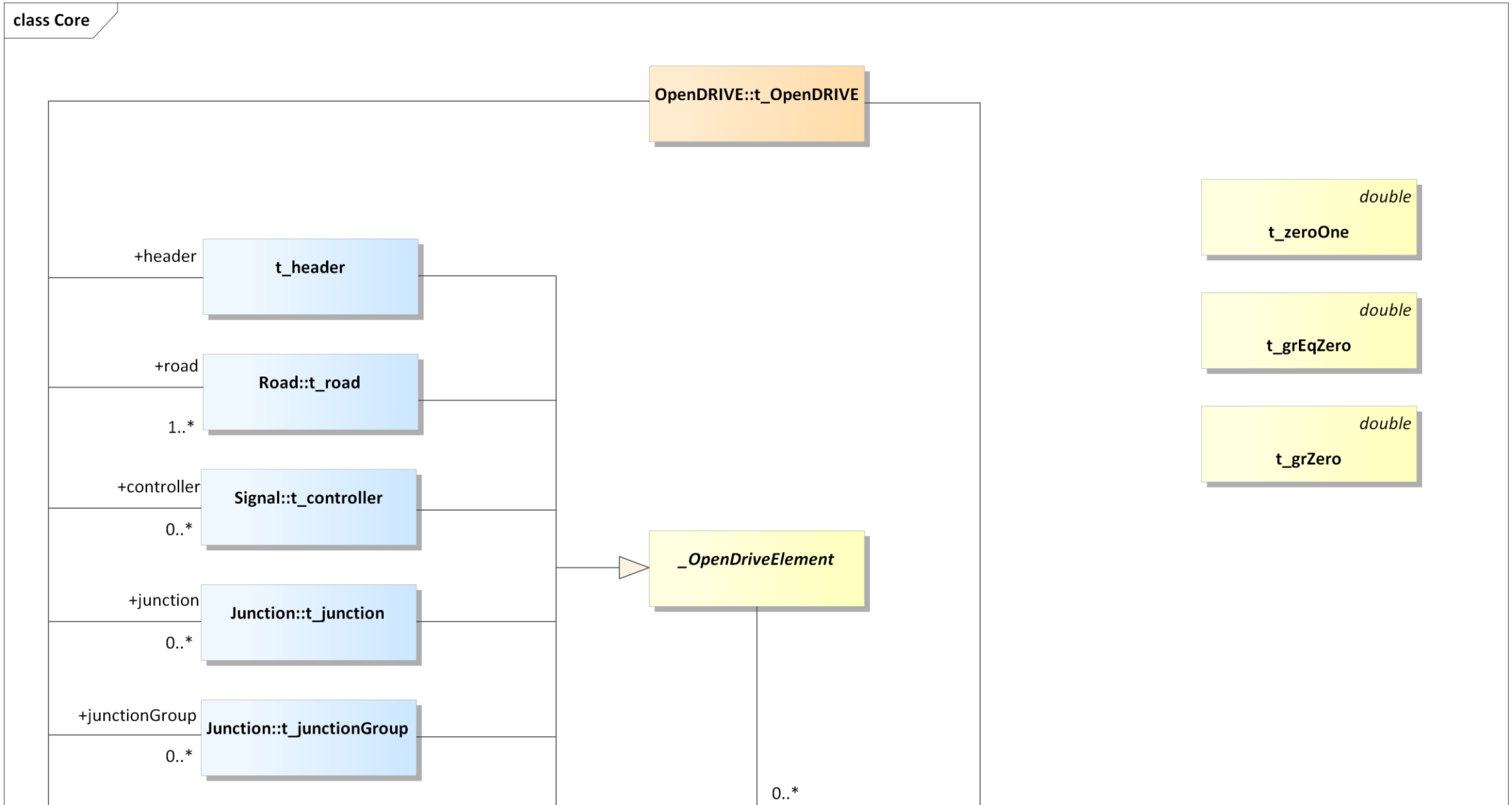
features

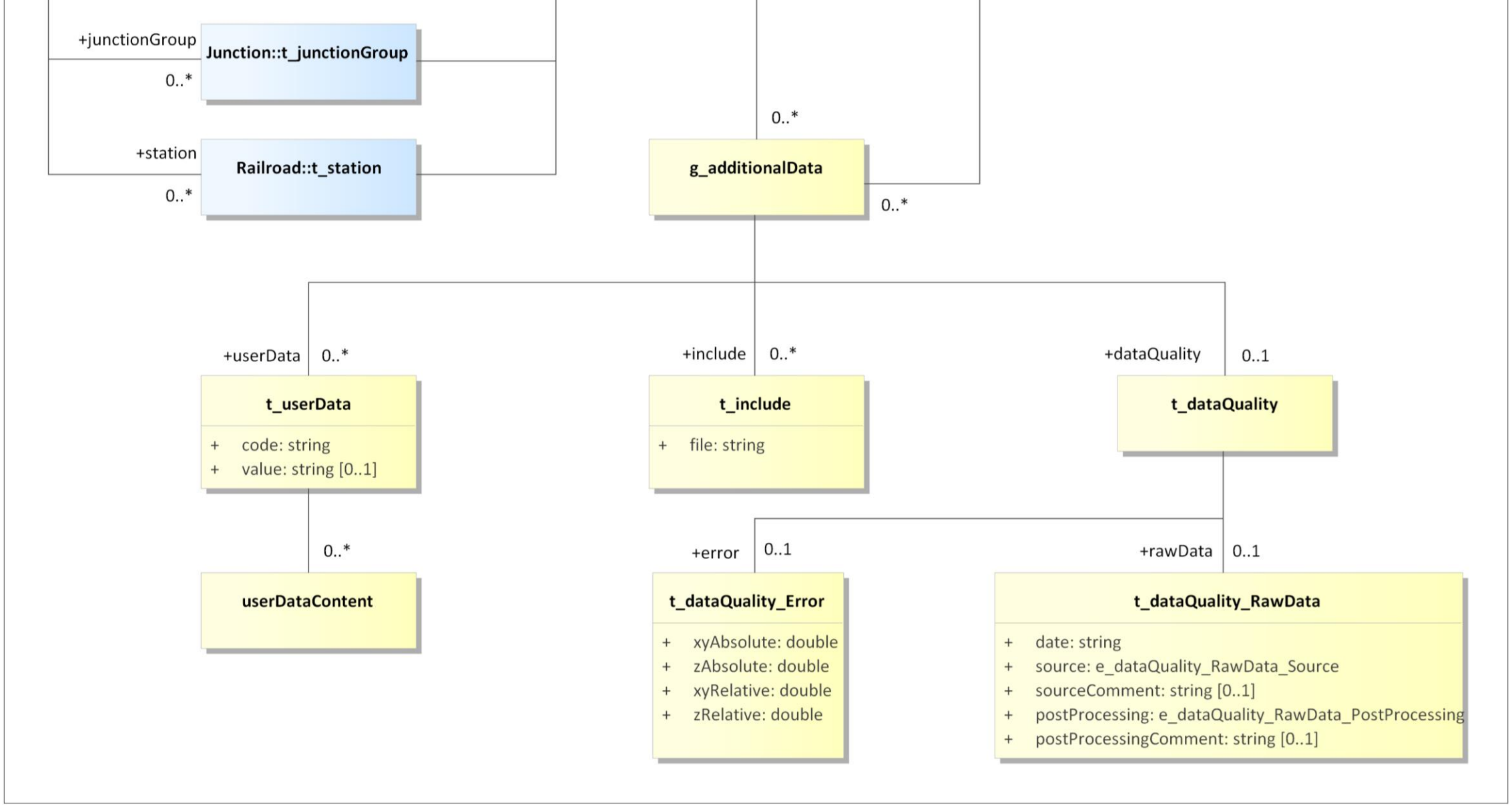




ASAM

ASAM OpenDRIVE Core

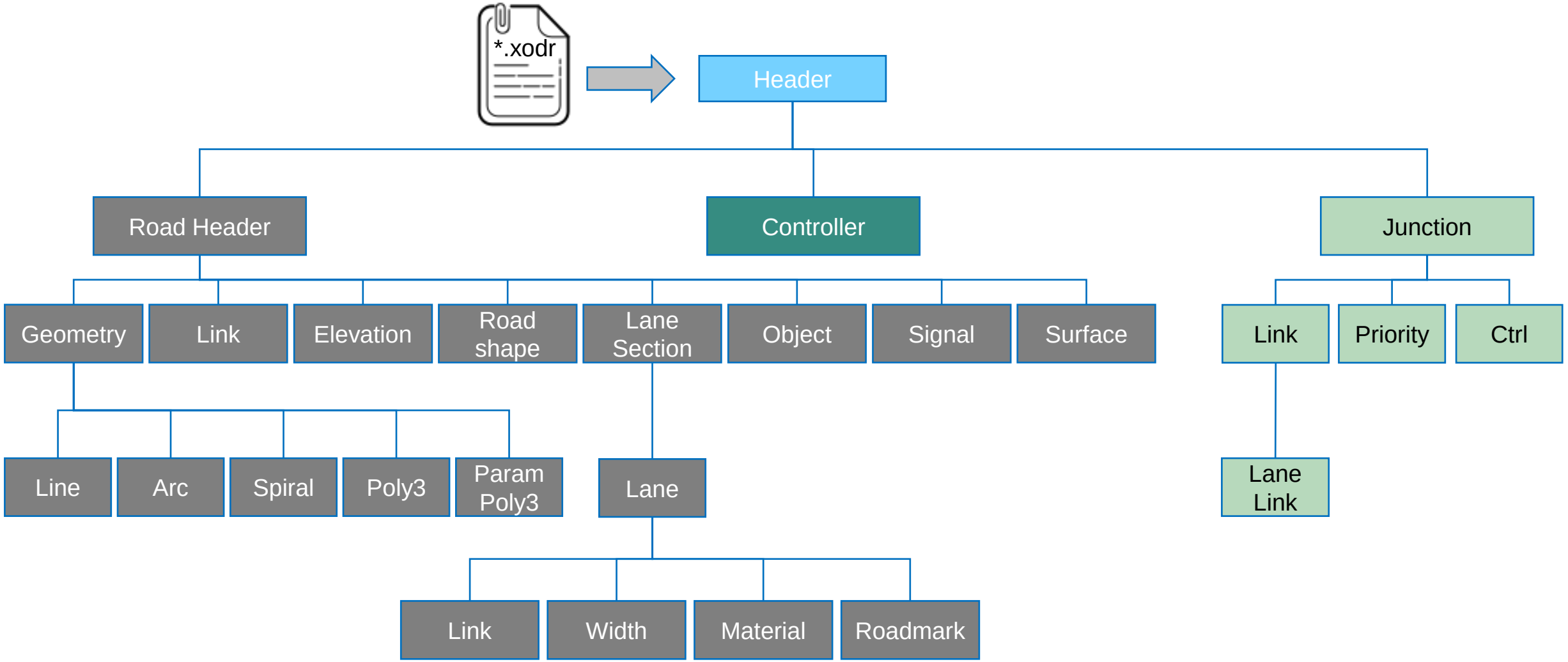



+junctionGroup
0..*
Junction::t_junctionGroup
+station
0..*
Railroad::t_station
0..*
g_additionalData
0..*
+userData
0..*
t_userData
+ code: string
+ value: string [0..1]
0..*
userDataContent
+include
0..*
t_include
+ file: string
+dataQuality
0..1
t_dataQuality
+error
0..1
t_dataQuality_Error
+ xyAbsolute: double
+ zAbsolute: double
+ xyRelative: double
+ zRelative: double
+rawData
0..1
t_dataQuality_RawData
+ date: string
+ source: e_dataQuality_RawData_Source
+ sourceComment: string [0..1]
+ postProcessing: e_dataQuality_RawData_PostProcessing
+ postProcessingComment: string [0..1]

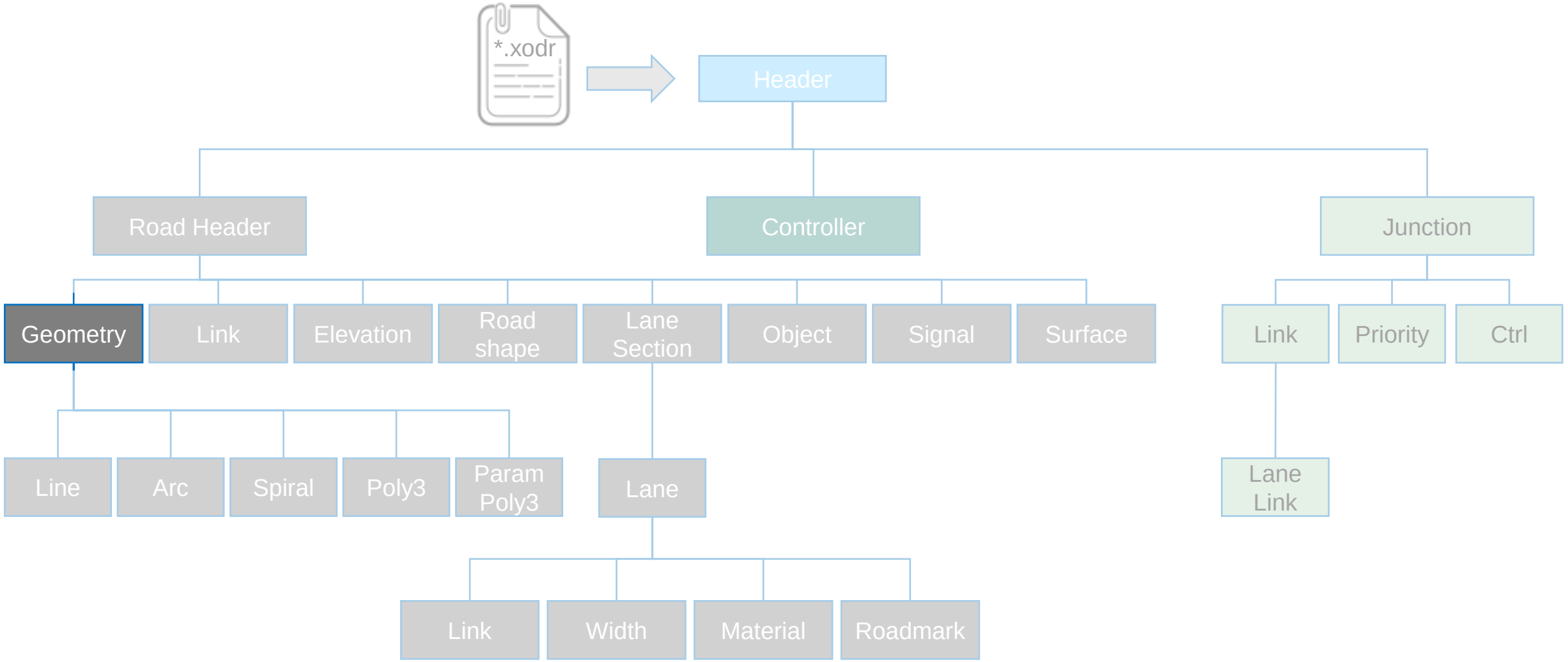
ASAM OpenDRIVE: XML Sturcture

```
<OpenDRIVE>
    <header></header>
    <road>
        <planView>
            <geometry></geometry>
        </planView>
        <elevationProfile></elevationProfile>
        <lateralProfile></lateralProfile>
        <lanes></lanes>
        <objects></objects>
        <signals></signals>
        <objects></objects>
    </road>
    <junction>
        <connection …>
    </junction>
    <controller></controller>
    <junctionGroup></junctionGroup>
</OpenDRIVE>
```

ASAM OpenDRIVE: Format



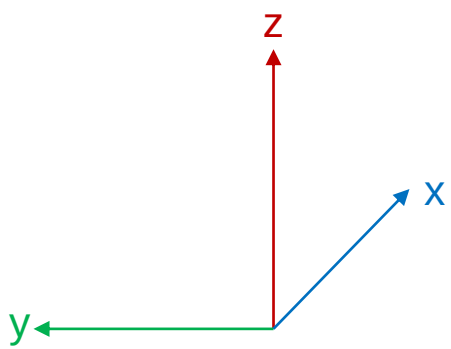
ASAM OpenDRIVE: Format



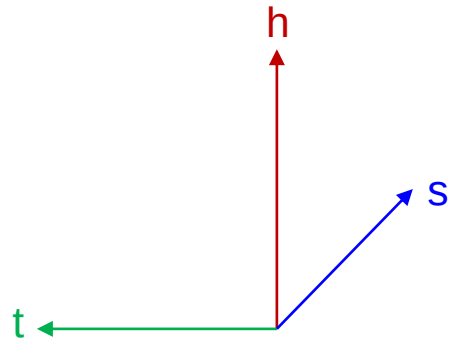
ASAM

ASAM OpenDRIVE: coordinate systems

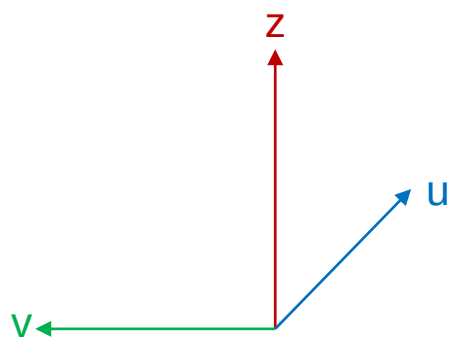
Inertial System



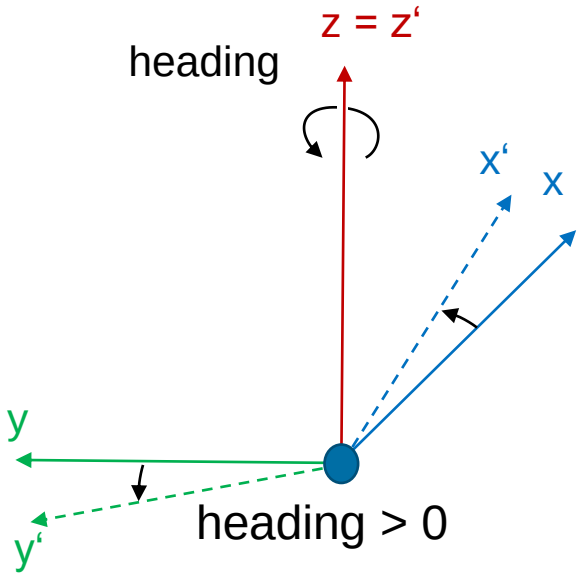
Reference Line System

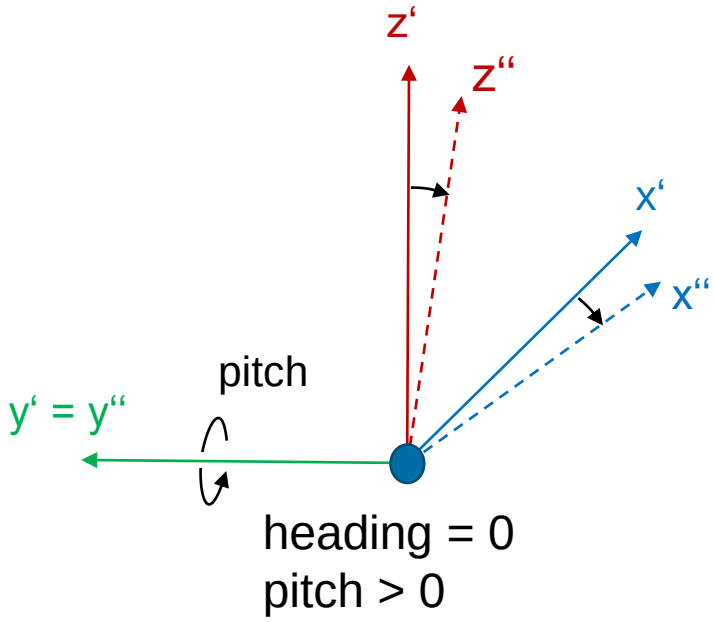


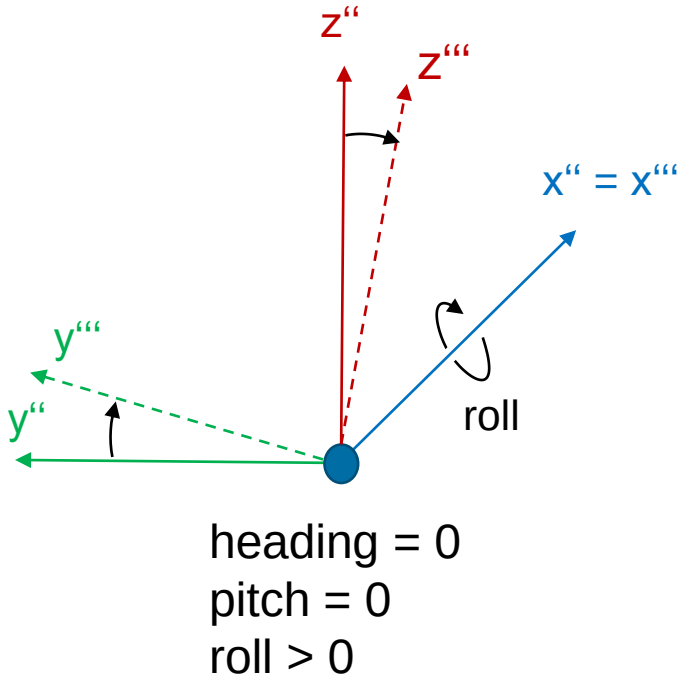
Local System



ASAM OpenDRIVE: Inertial coordinate system

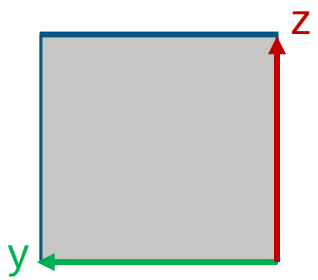




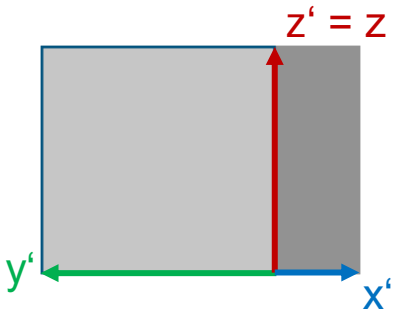


ASAM OpenDRIVE: inertial coordinate system

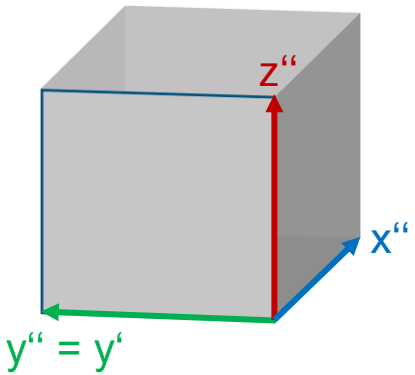
heading = 0
pitch = 0
roll = 0



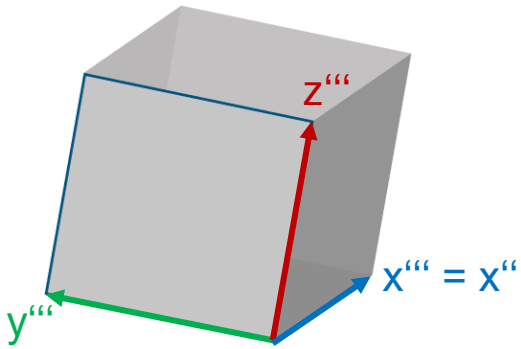
heading < 0
pitch = 0
roll = 0



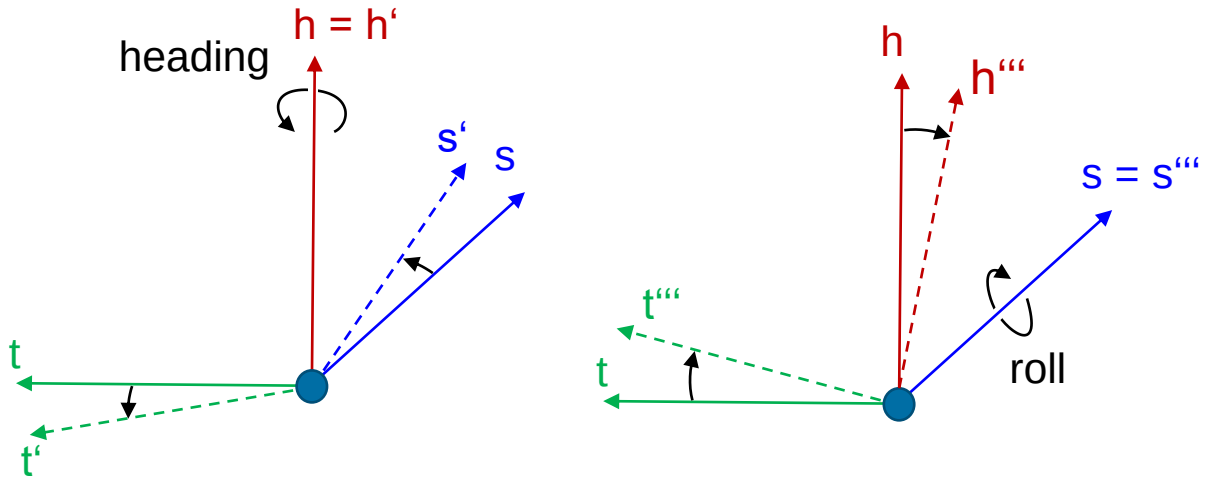
heading < 0
pitch < 0
roll = 0



heading < 0
pitch < 0
roll > 0

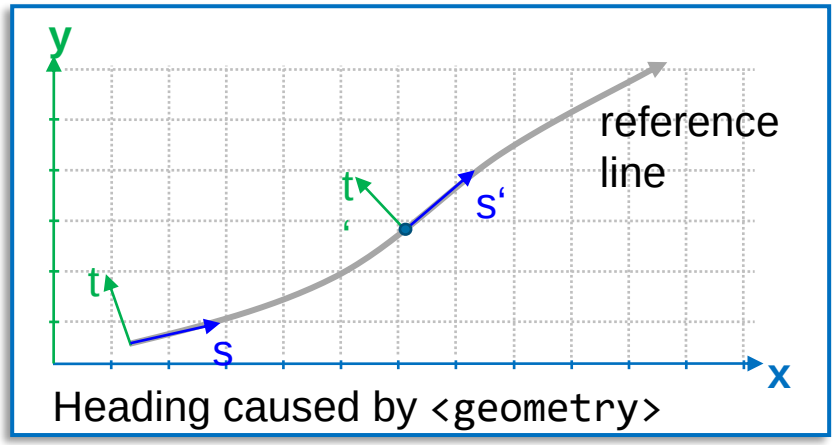


ASAM OpenDRIVE: reference line coordinate system

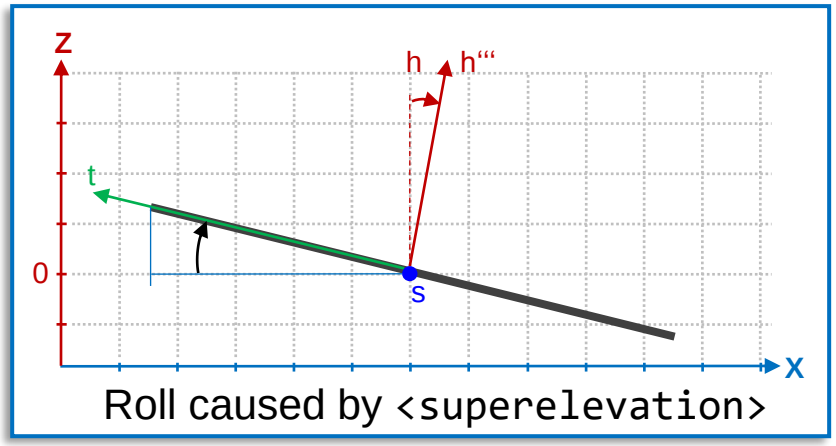


In the reference line coordinate system, there is no pitch

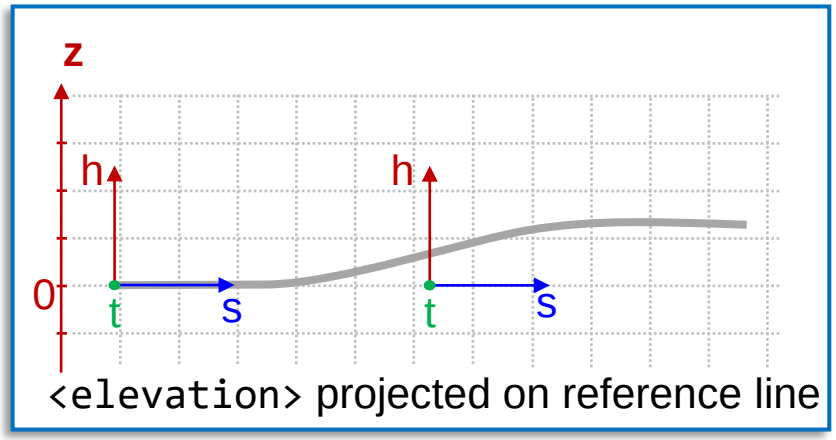
ASAM OpenDRIVE: reference line coordinate system



Heading caused by <geometry>



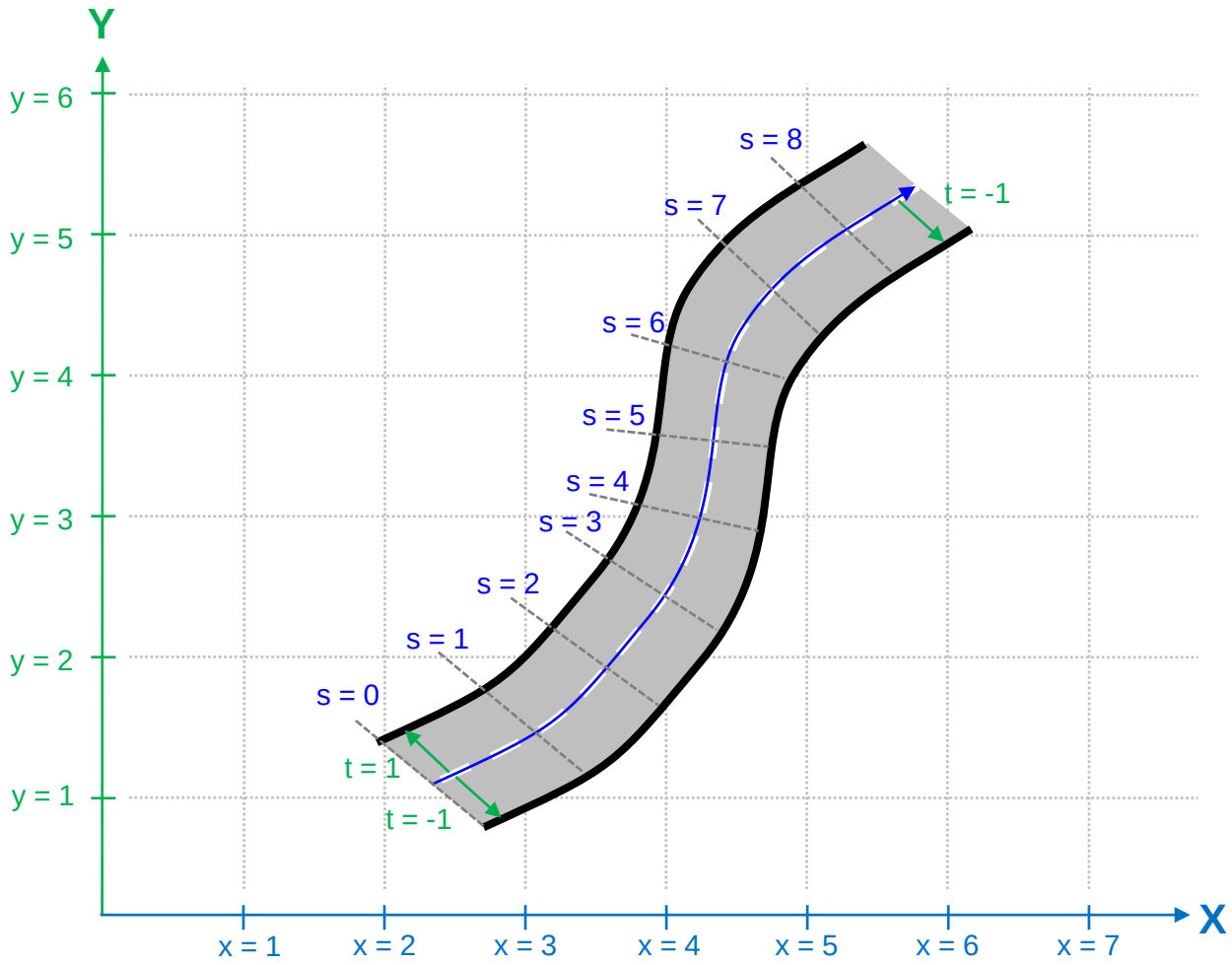
Roll caused by <superelevation>



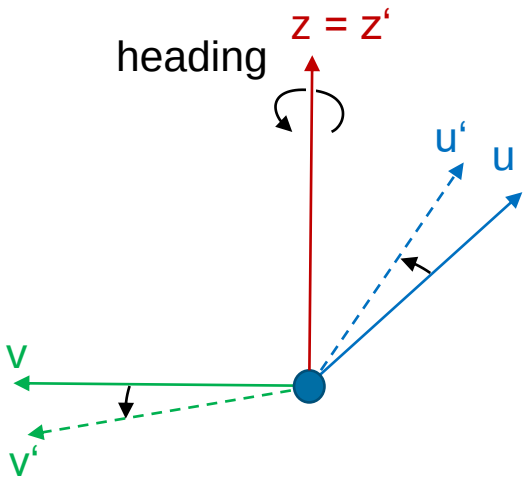
<elevation> projected on reference line

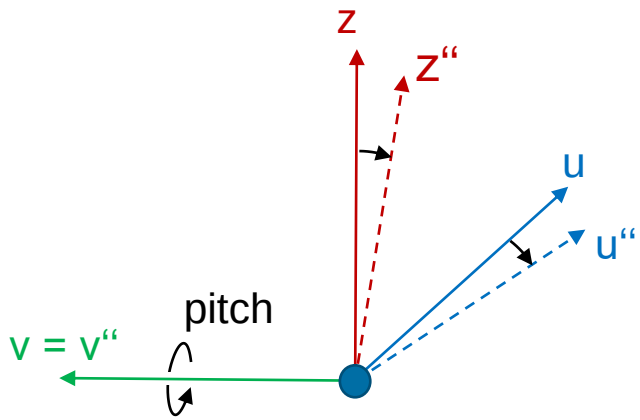
In the reference line coordinate system is no pitch available.
In case the eference line is elevated, the elevation does not effect the length of s

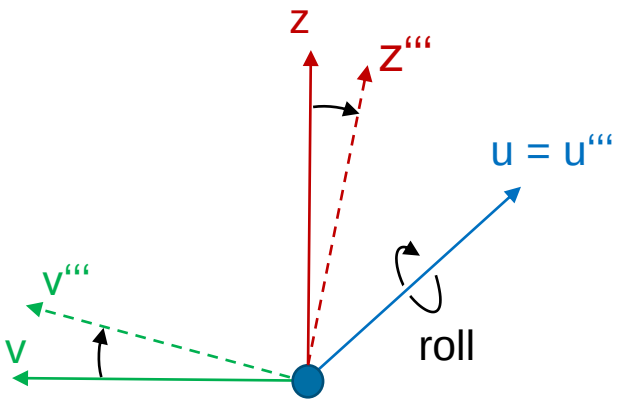
ASAM OpenDRIVE: x/y and s/t Systems



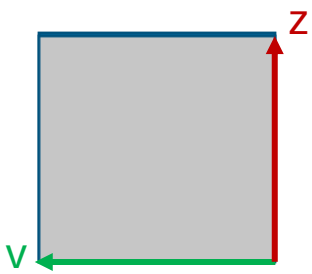
ASAM OpenDRIVE: Local coordinate system



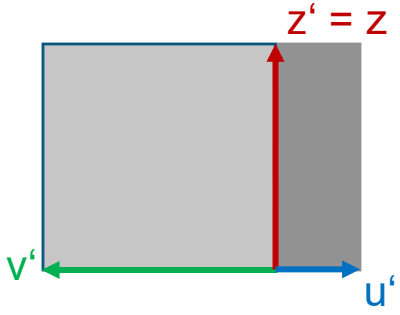




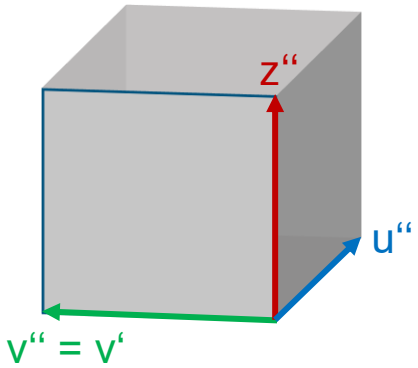
heading = 0
pitch = 0
roll = 0



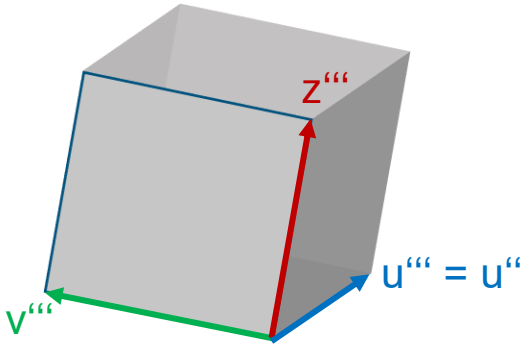
heading < 0
pitch = 0
roll = 0



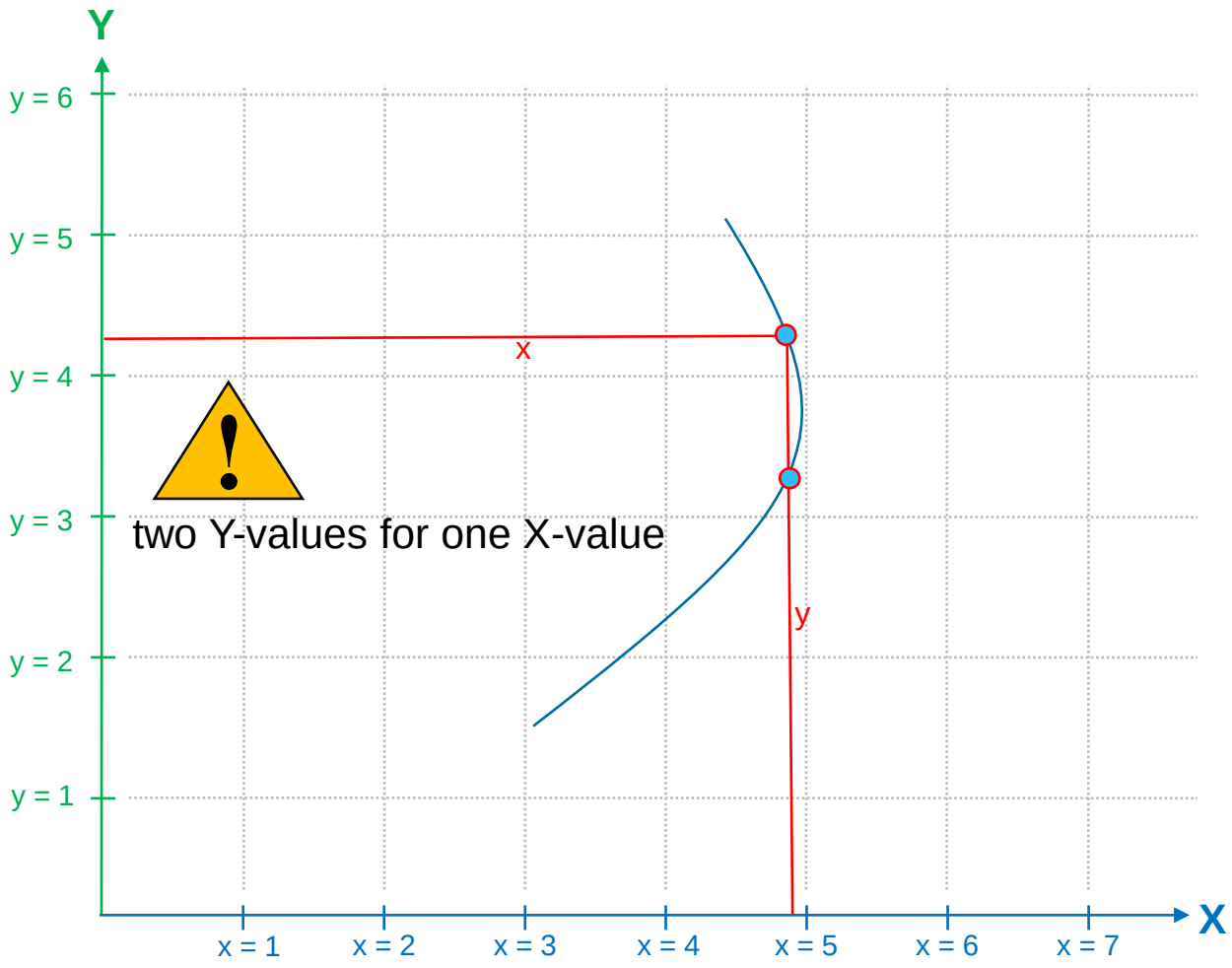
heading < 0
pitch < 0
roll = 0



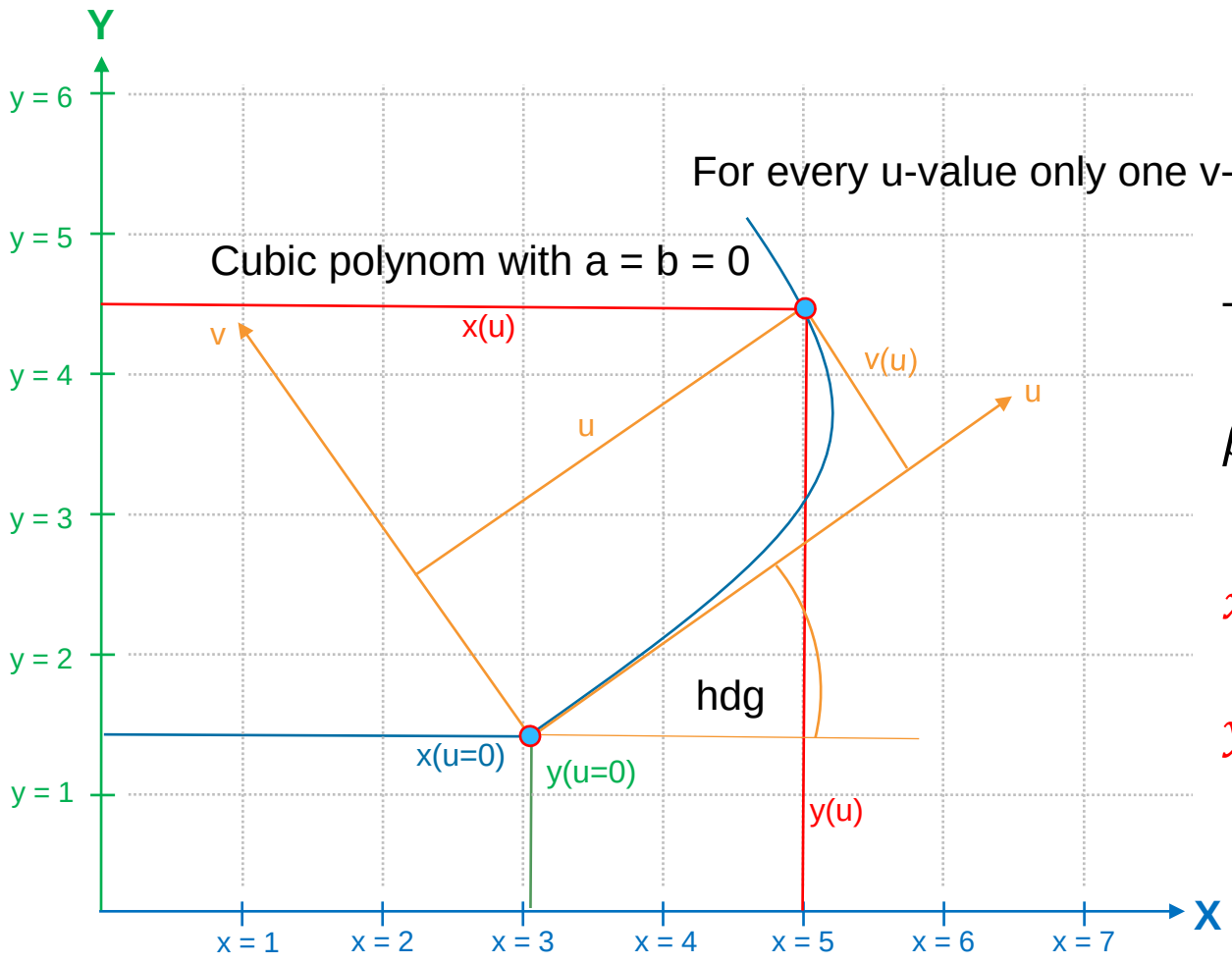
heading < 0
pitch < 0
roll > 0



ASAM OpenDRIVE: Usage of the Local system



ASAM OpenDRIVE: Point Tranformation



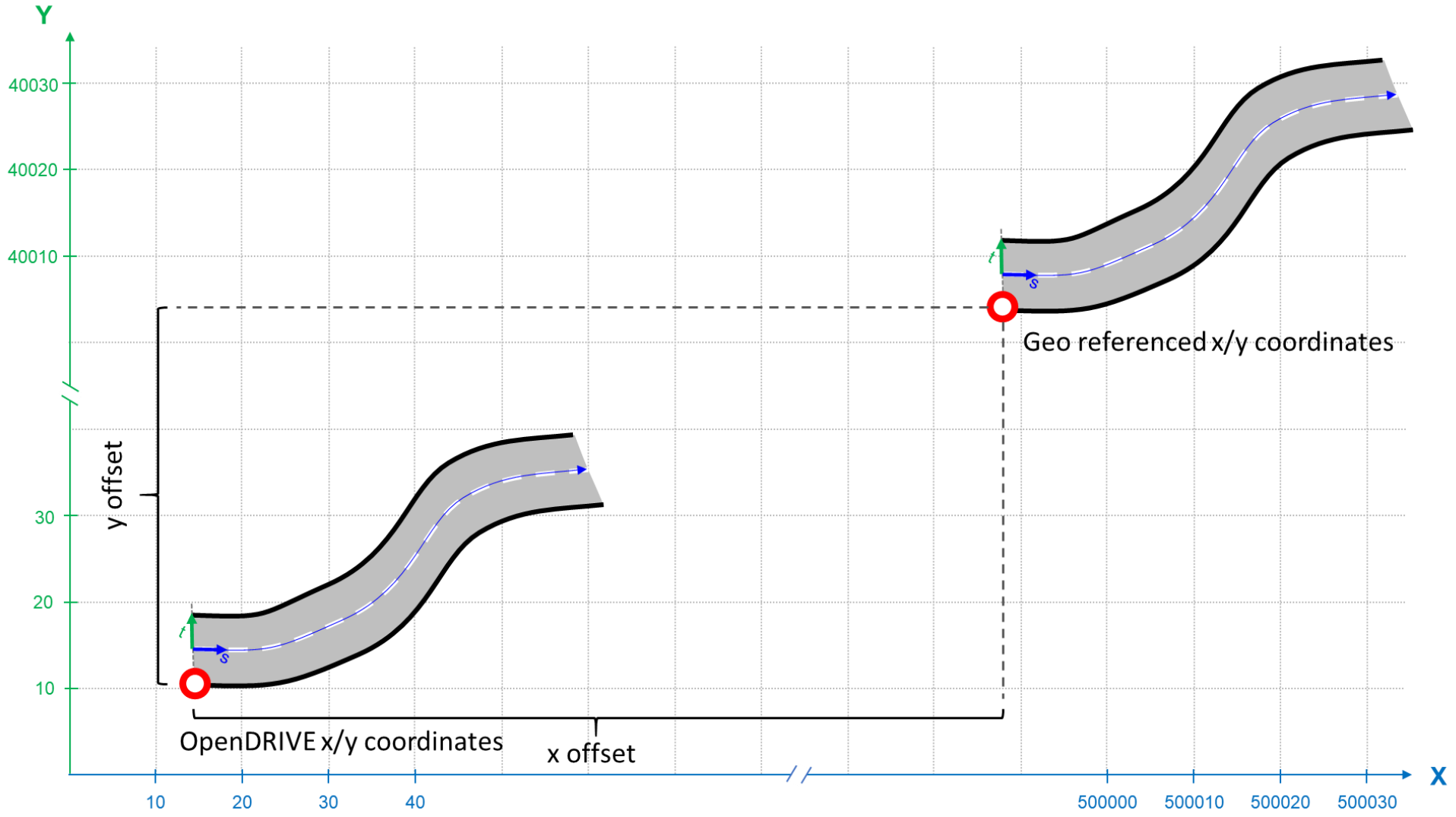
Transformation from u/v to x/y

$$\beta = hdg + arctan(v(u)/u)$$

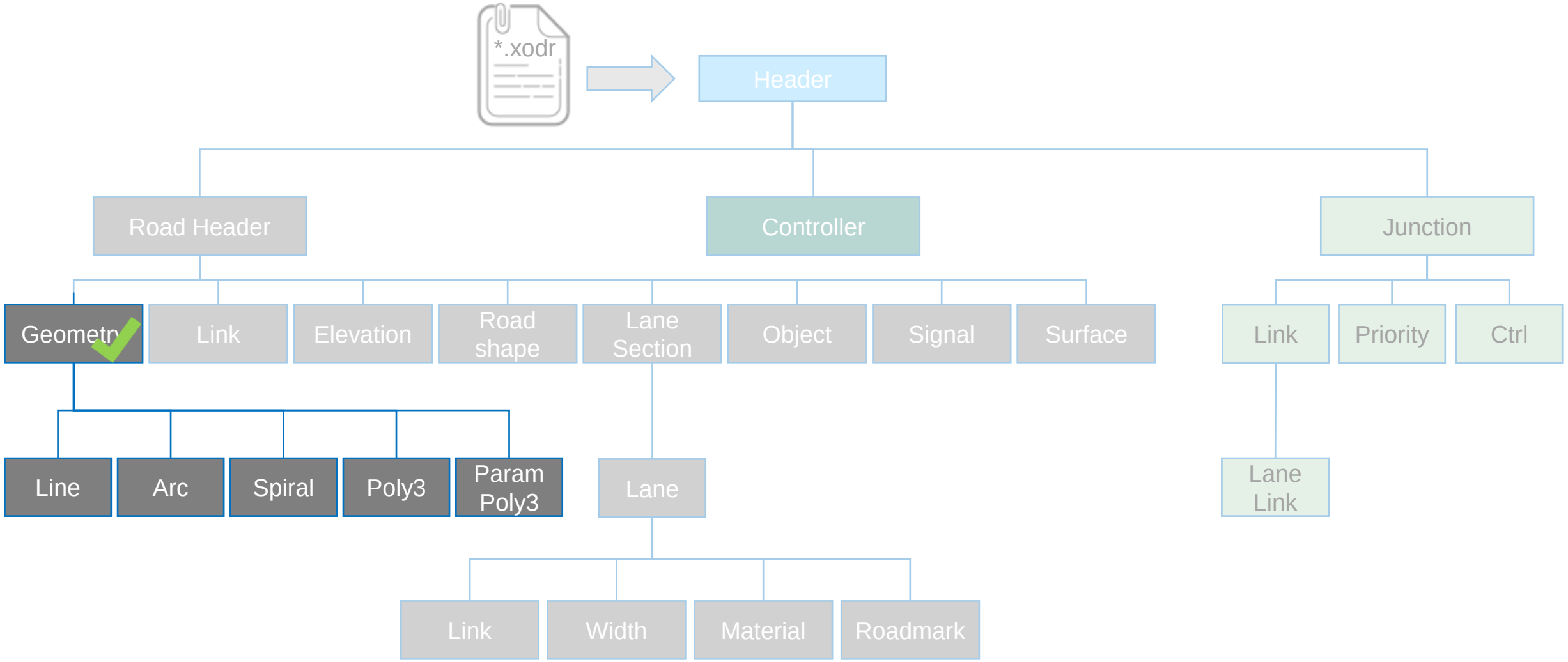
$$x(u) = x(u=0) + \sqrt{u^2 + v(u)^2} * \cos(\beta)$$

$$y(u) = y(u=0) + \sqrt{u^2 + v(u)^2} * sin(\beta)$$

ASAM OpenDRIVE: Georeferencing

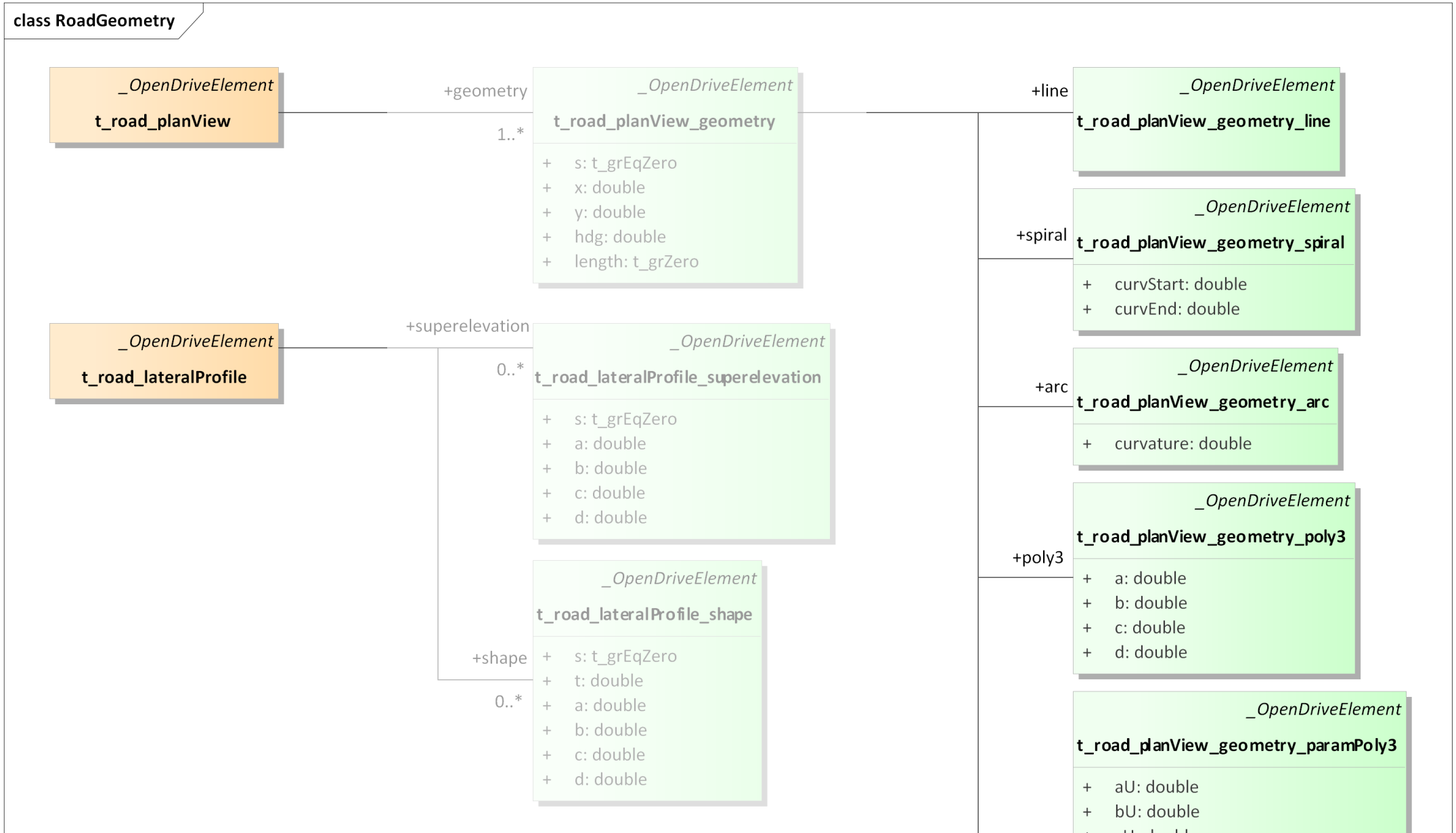


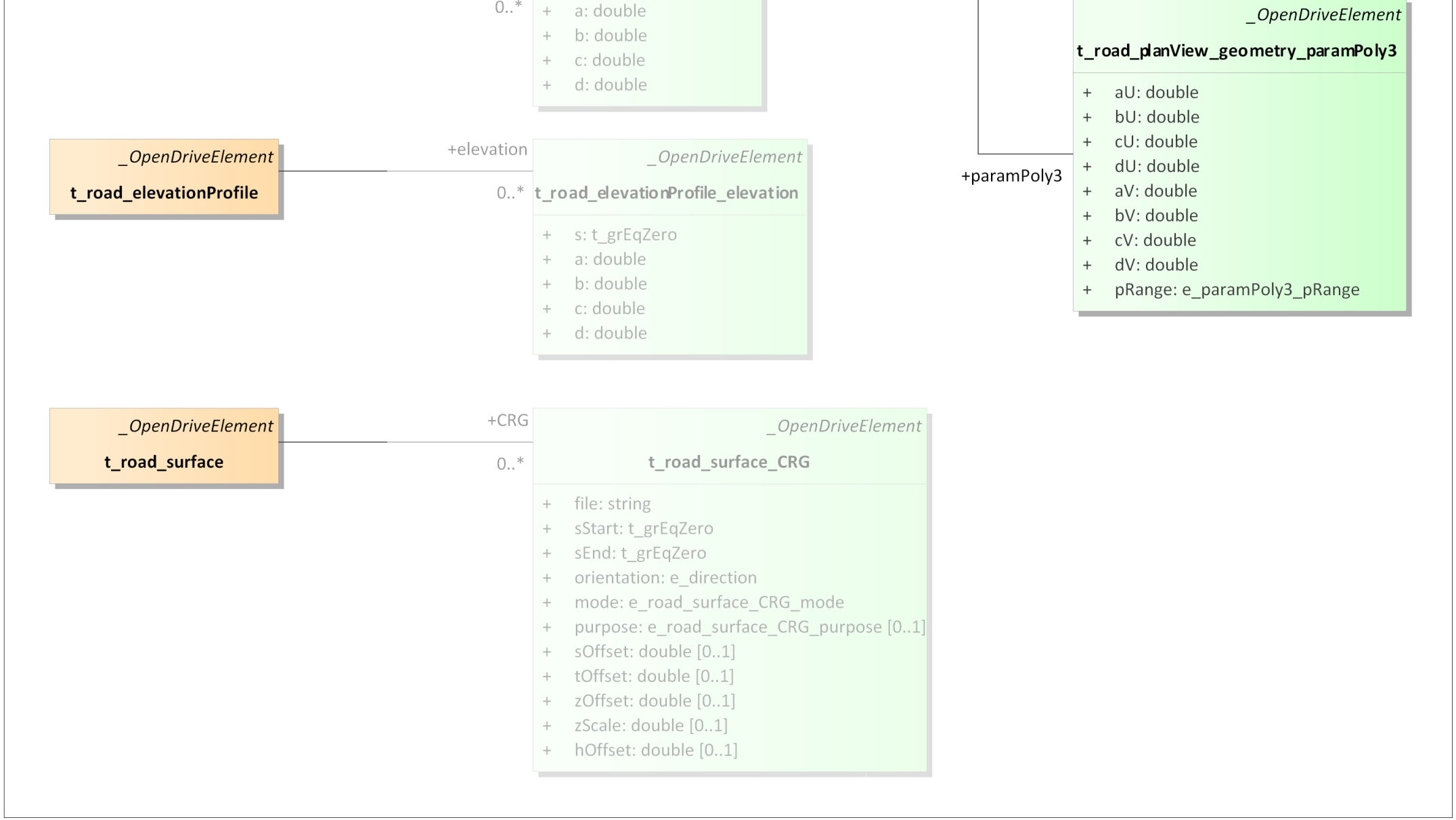
ASAM OpenDRIVE: Format



ASAM

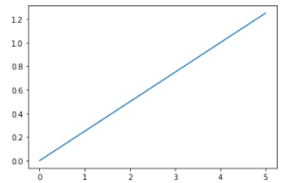
ASAM OpenDRIVE: Geometry




0..*
+ a: double
+ b: double
+ c: double
+ d: double
_OpenDriveElement
t_road_elevationProfile
+elevation
0..*
_OpenDriveElement
t_road_elevationProfile_elevation
+ s: t_grEqZero
+ a: double
+ b: double
+ c: double
+ d: double
_OpenDriveElement
t_road_surface
+CRG
0..*
_OpenDriveElement
t_road_surface_CRG
+ file: string
+ sStart: t_grEqZero
+ sEnd: t_grEqZero
+ orientation: e_direction
+ mode: e_road_surface_CRG_mode
+ purpose: e_road_surface_CRG_purpose [0..1]
+ sOffset: double [0..1]
+ tOffset: double [0..1]
+ zOffset: double [0..1]
+ zScale: double [0..1]
+ hOffset: double [0..1]
+paramPoly3
_OpenDriveElement
t_road_planView_geometry_paramPoly3
+ aU: double
+ bU: double
+ cU: double
+ dU: double
+ aV: double
+ bV: double
+ cV: double
+ dV: double
+ pRange: e_paramPoly3_pRange

Referenc Line Elements

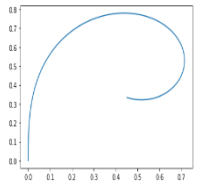
straight lines



$\frac{\Delta\alpha}{\Delta t} = 0°$

$\alpha_{time=0} = 0°$

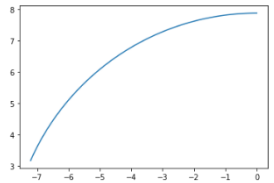
spirals



$\frac{\Delta\alpha}{\Delta t} = x°$

$\alpha_{time=0} = 0°$

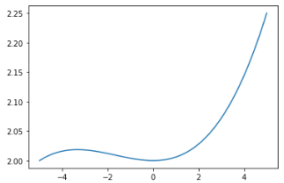
arcs



$\frac{\Delta\alpha}{\Delta t} = 0°$

$\alpha_{time=0} = n°$

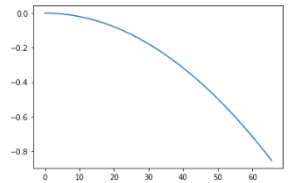
cubic polynomials



$\frac{\Delta\alpha}{\Delta t} = f(x°)$

$\alpha_{time=0} = n°$

Parametric cubic polynomials



$\frac{\Delta\alpha}{\Delta t} = f(x°)$

$\alpha_{time=0} = n°$

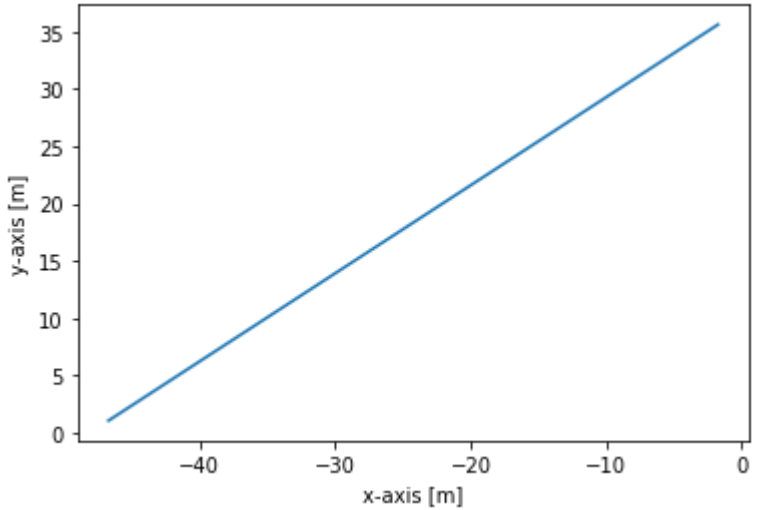
delimiters: <geometry>…</geometry>
parent: <planView>
instances: 1+
attributes:

name	*type*	*unit*	*value*	*description*
s	double	m	$[0, \infty[$	
x	double	m	$]-\infty, \infty[$	
y	double	m	$]-\infty, \infty[$	
hdg	double	rad	$]-\infty, \infty[$	
length	double	m	$[0, \infty[$	

Reference Line Modelling: Line

In OpenDRIVE the line segement is defines as a vector wir length and heading

```
<planView>
    <geometry    s="0.0000000000000000e+00"
                 x="-4.7170752711170401e+01"
                 y="7.2847983820912710e-01"
                 hdg="6.5477882613167993e-01"
                 length="5.7280000000000000e+01">
                 <line/>
     </geometry>
```



ASAM

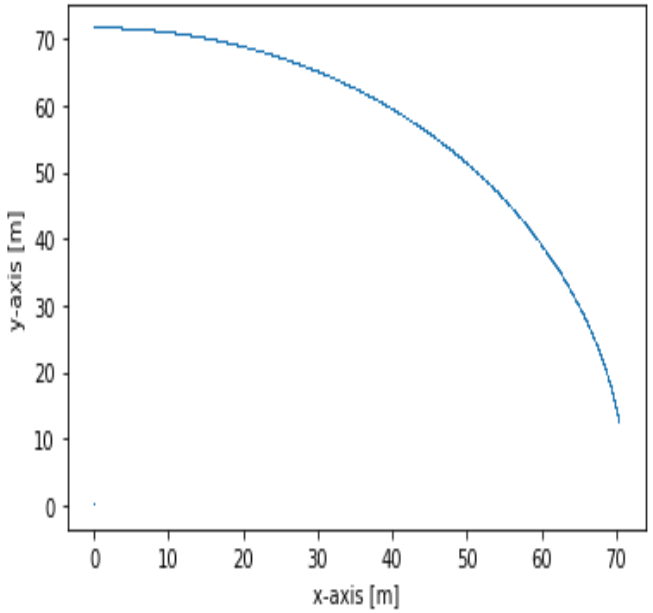
Reference Line Modelling: Arc

Arc: constant curvature throughout the element

Formular:

$$u_{local} = \frac{1}{curvature} * \sin\left(\frac{length * curvature * 360°}{2 * \pi}\right)$$

$$v_{local} = \frac{1}{curvature} * \cos\left(\frac{length * curvature * 360°}{2 * \pi}\right)$$

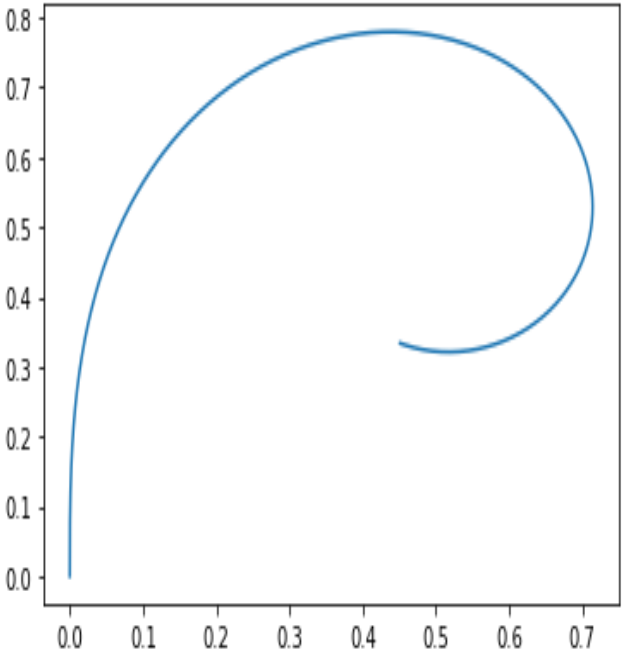



```
<planView>
    <geometry    s="3.6612031746270386e+00"
                 x="-4.6416930098385274e+00"
                 y="4.3409250448366459e+00"
                 hdg="5.2962250374496271e+00"
                 length="9.1954178989066371e+00">
                 <arc curvature="-1.2698412698412698e-01"/>
    </geometry>
```

Reference Line Modelling: Spiral

Spiral: The Spiral a changing curavture from start to end

```
<geometry
        s="100.0"
        x="38.00"
        y="-1.81"
        hdg="0.33"
        length="30.00">
        <spiral
                curvStart="0.0"
                curvEnd="0.013"/>
</geometry>
```



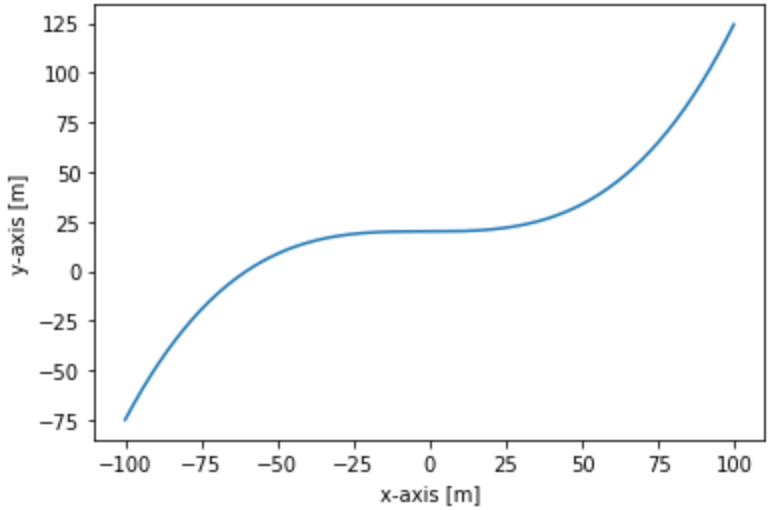
Source: https://scipython.com/book/chapter-8-scipy/examples/the-euler-spiral/

Reference Line Modelling: Cubic Poylnomial

Formular:

$$v = a + b * u + c * u^2 + d * u^3$$

```
<geometry
        s="0.0"
        x="-1.00e+2 "
        y= "-7.5e+1"
        hdg="0.0"
        length="2.56e+02">
        <poly3
                a="2.0000000000000000e+01"
                b="0.0000000000000000e+00"
                c="5.0e-04"
                d="1.0e-04"/>
</geometry>
```



https://groups.uni-paderborn.de/reiss/AnalyseBuch/Grundlagen/Polynome/Polynom3.html

Reference Line Modelling: Parametric Cubic Polynomial

Formular:

$$v_{local} = av + bv * p + cv * p^2 + dv * p^3$$
$$u_{local} = au + bu * p + cu * p^2 + du * p^3$$

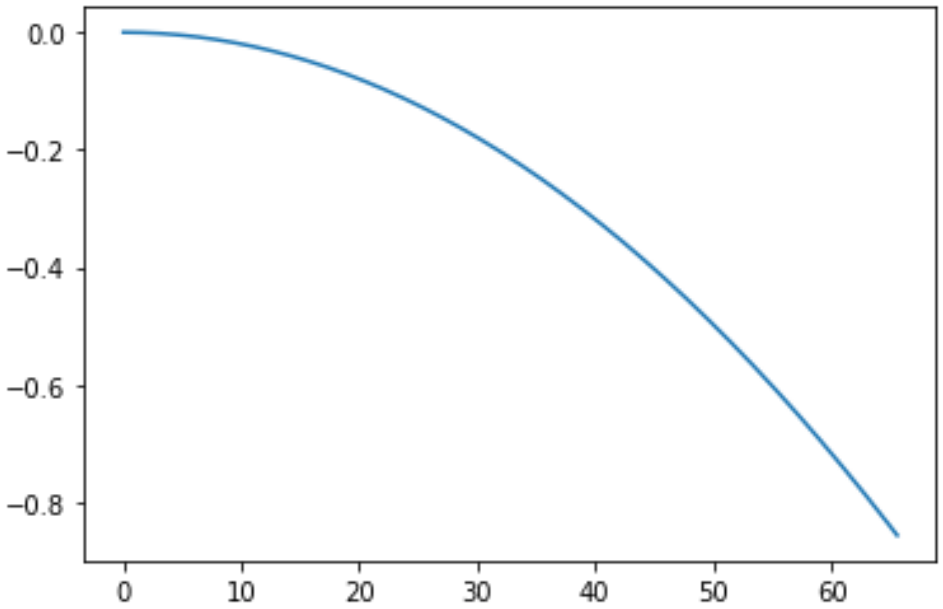
Example

```
def parampoly3(s, length, aU, bU, cU, dU, aV, bV, cV, dV, samplePoints):
    u = []
    v = []
    increment = length/samplePoints
    p=0.0
    while p <= length:
        ulocal = aU +bU*p + cU*p*p +dU*p*p*p
        vlocal = aV +bV*p + cV*p*p +dV*p*p*p
        u.append(ulocal)
        v.append(vlocal)
        p = p+increment
    return u,v
```

Reference Line Modelling: Parametric Cubic Polynomial

Example, Source : https://service.mdm-portal.de

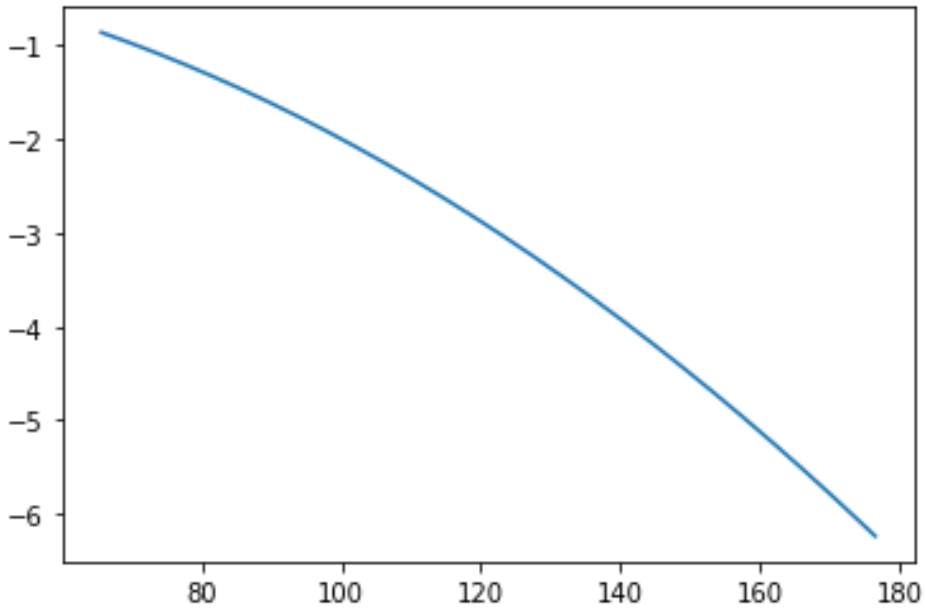
```
<planView>
      <geometry
        s="0.000000000000e+00"
        x="6.804539427645e+05"
        y="5.422483642942e+06"
        hdg="5.287405485081e+00"
        length="6.565893957370e+01">
        <paramPoly3
                aU="0.000000000000e+00"
                bU="1.000000000000e+00"
                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" />
      </geometry>
```



Reference Line Modelling: Parametric Cubic Polynomial

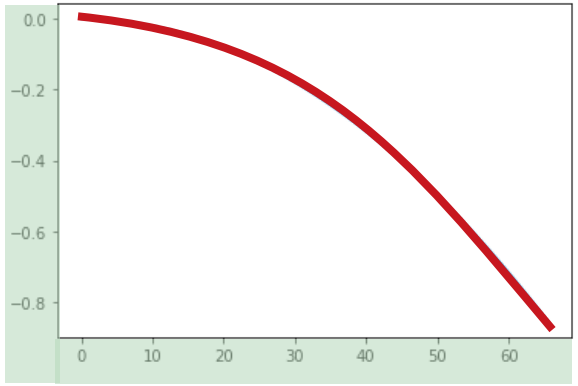
Example, Source : https://service.mdm-portal.de

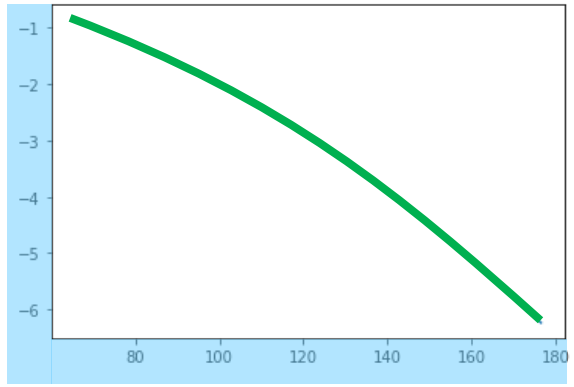
```
<planView>
      <geometry
        s="6.565893957370e+01"
        x="6.804889277964e+05"
        y="5.422428083076e+06"
        hdg="5.261283044587e+00"
        length="1.110588988589e+02">
        <paramPoly3
                aU=0.000000000000e+00
                bU=1.000000440816e+00
                cU=1.565116500014e-08
                dU=-2.677076827090e-08
                aV=0.000000000000e+00
                bV=2.775557561563e-16
                cV=-1.990999469114e-04
                dV=-4.787206386470e-09
                pRange="arcLength" />
      </geometry>
```

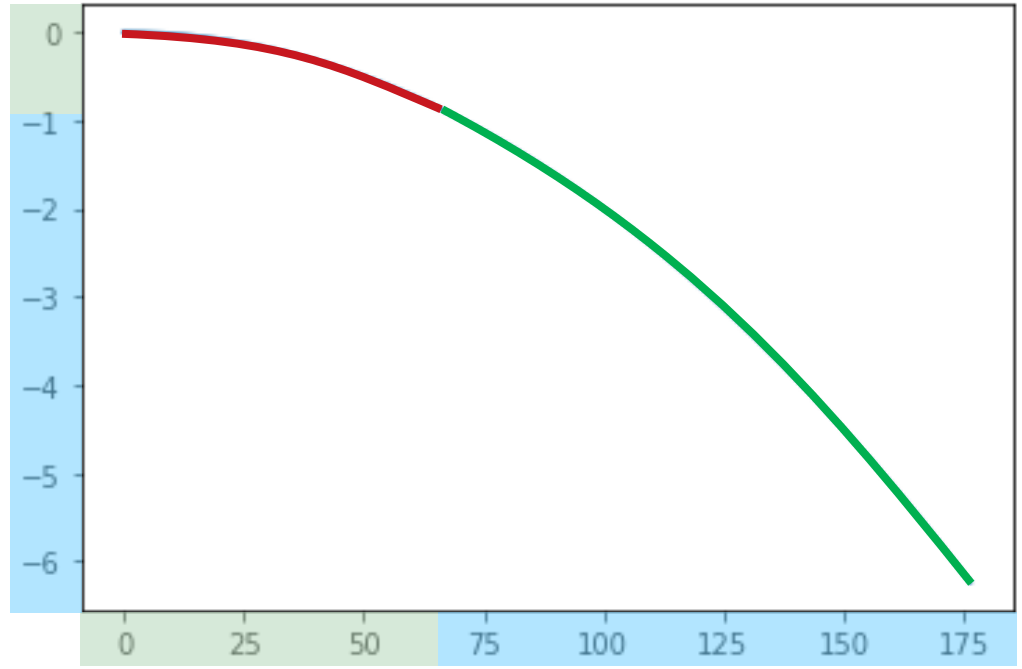


Referenc Line: adding two primitives together

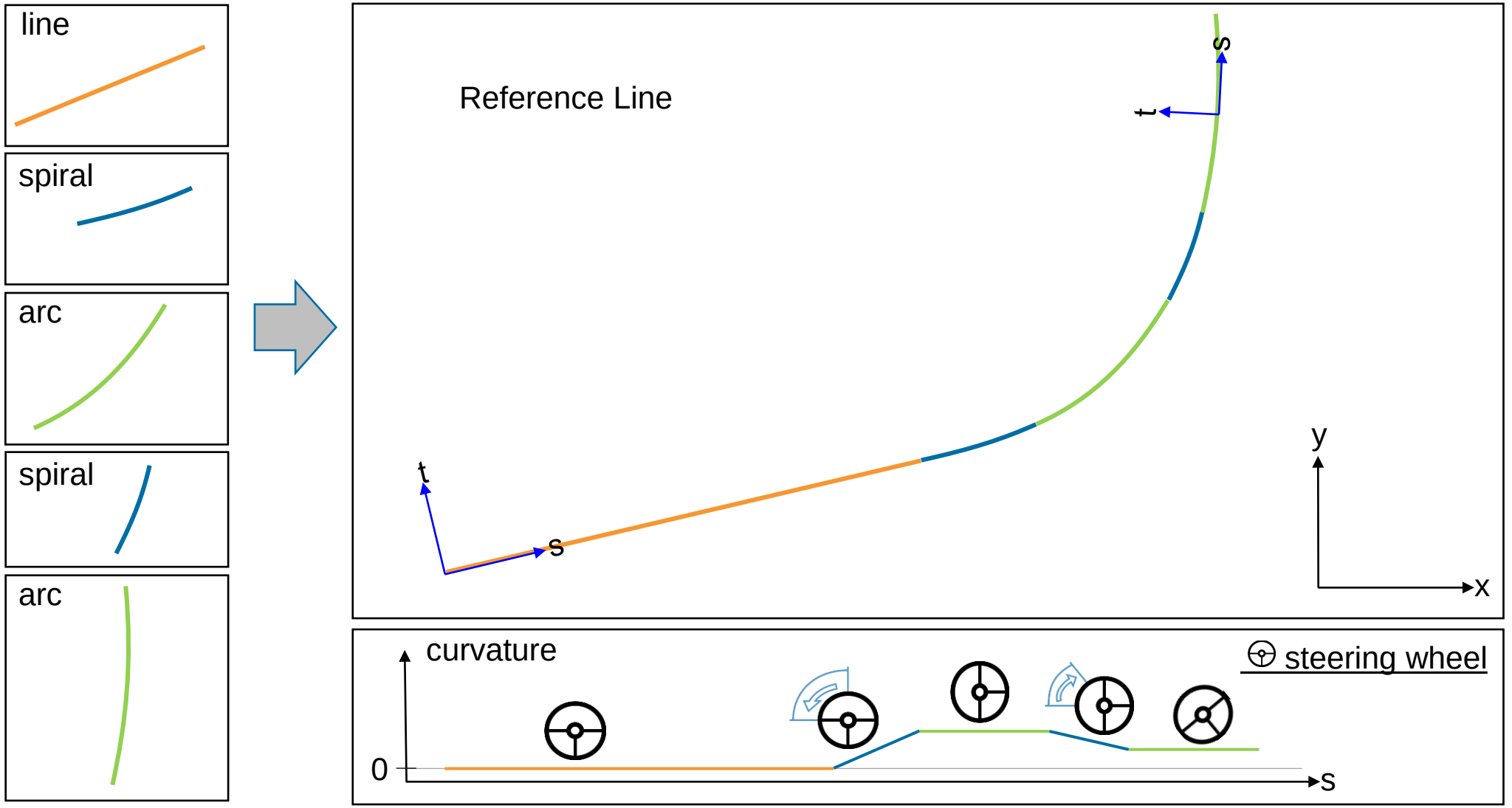
```
<planView>
      <geometry
        s="0.000000000000e+00"
        x="6.804539427645e+05"
        y="5.422483642942e+06"
        hdg="5.287405485081e+00"
        length="6.565893957370e+01">
        <paramPoly3
                aU="0.000000000000e+00"
                bU="1.000000000000e+00"
                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" />
      </geometry>
      <geometry
        s="6.565893957370e+01"
        x="6.804889277964e+05"
        y="5.422428083076e+06"
        hdg="5.261283044587e+00"
        length="1.110588988589e+02">
        <paramPoly3
                aU=0.000000000000e+00
                bU=1.000000440816e+00
                cU=1.565116500014e-08
                dU=-2.677076827090e-08
                aV=0.000000000000e+00
                bV=2.775557561563e-16
                cV=-1.990999469114e-04
                dV=-4.787206386470e-09
                pRange="arcLength" />
      </geometry>
```



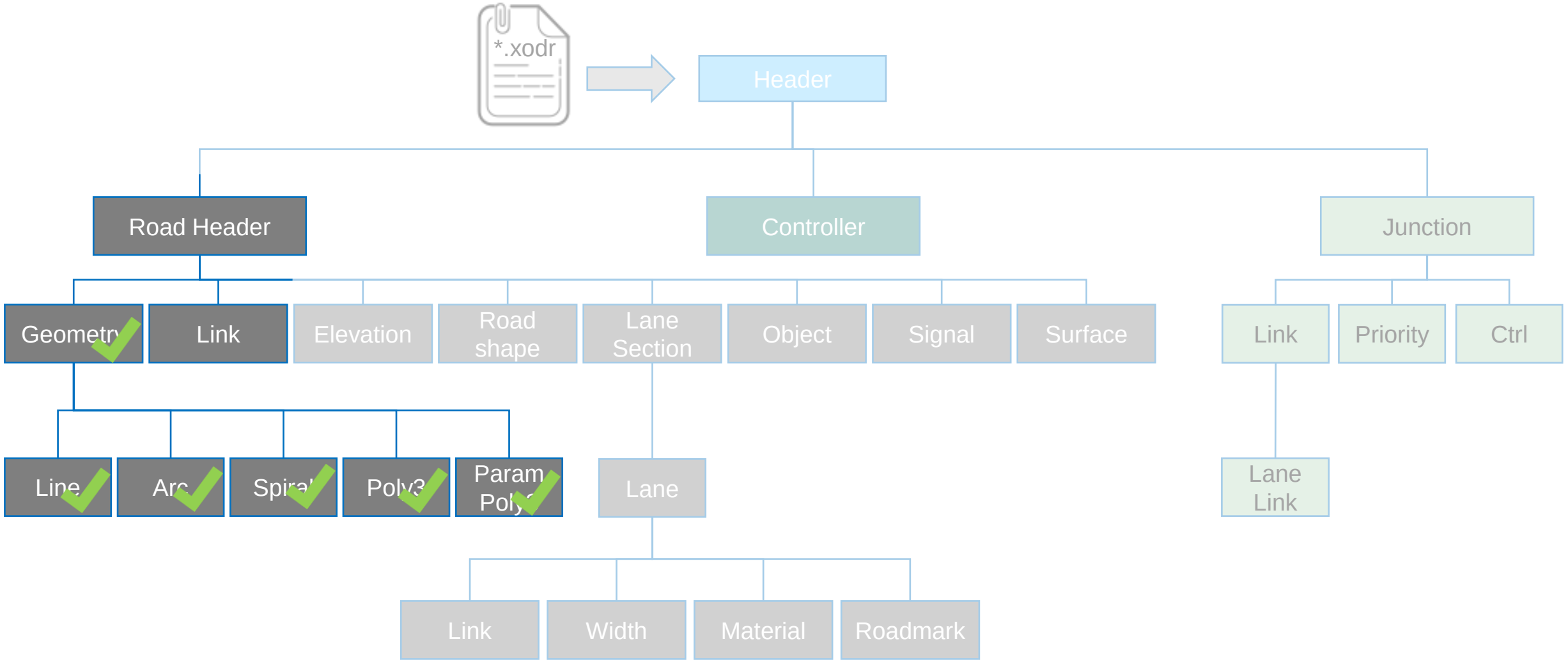




ASAM OpenDRIVE: Reference Line - Primitives

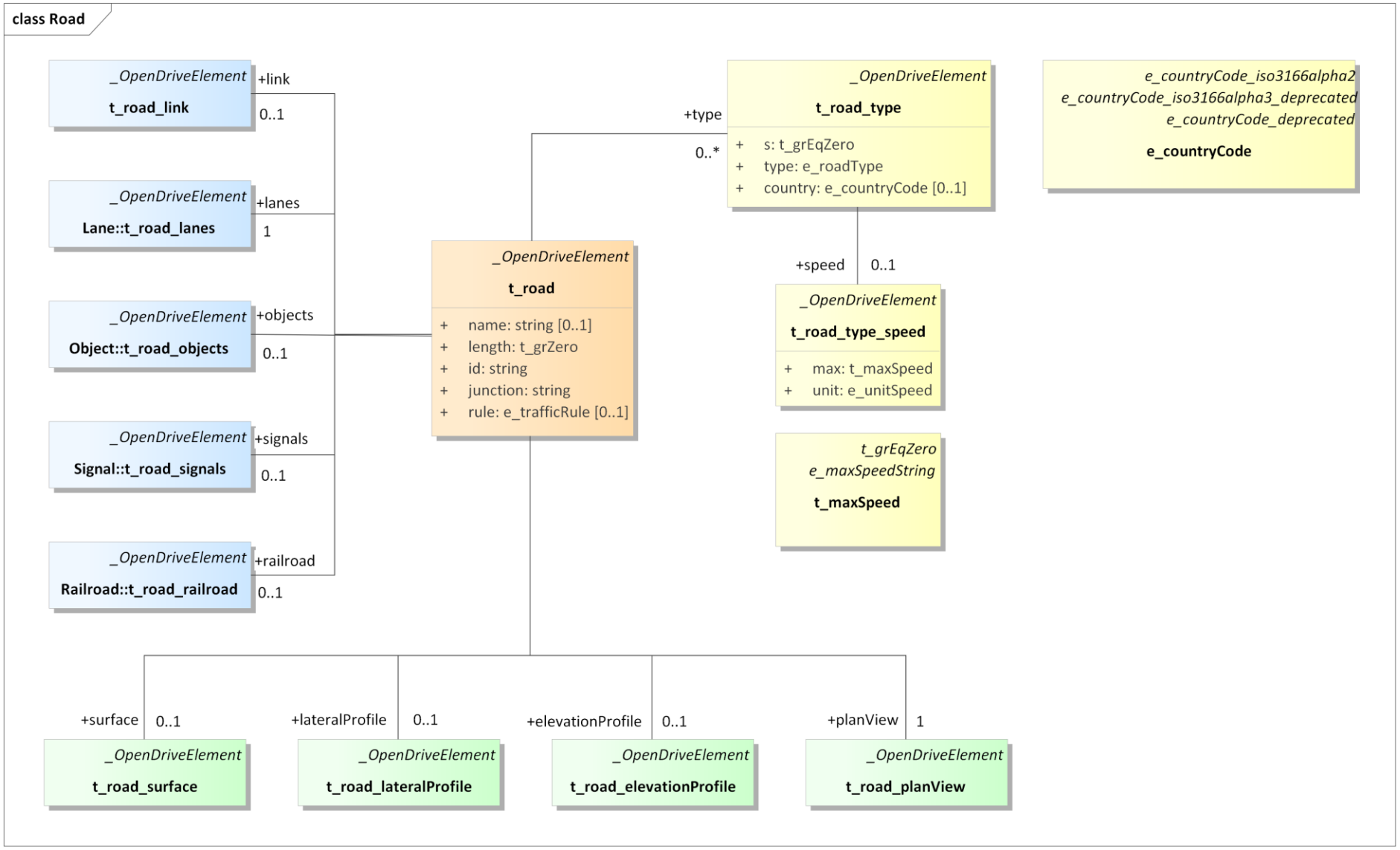


ASAM OpenDRIVE: Format

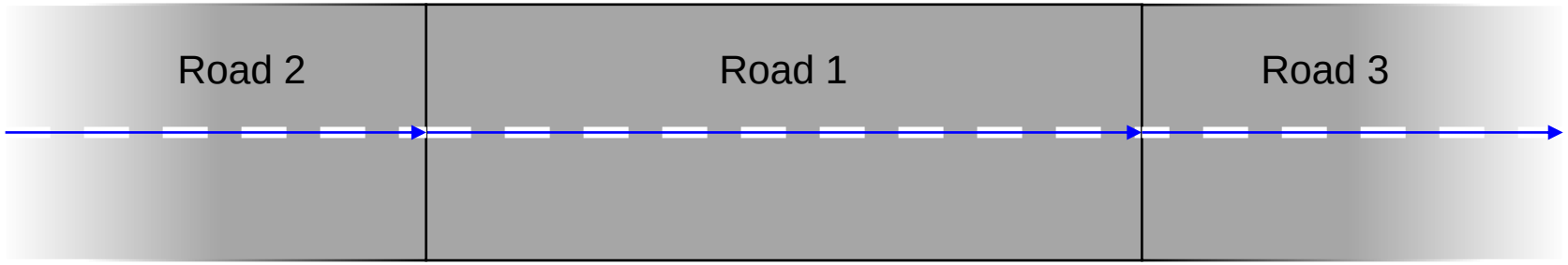


ASAM

ASAM OpenDRIVE: Roads



Road Definition



Basic road definition example (Road 1)

- 100 m long
- Straight road with two lanes
- Broken line between the lanes
- Linked to a predessor road and a successor road

Road Definition

1. Define the road header:

```
<road rule="RHT" name= "example_road" length="1.00e+02" id="1" junction="-1">
```

2. Define the road link:

```
<link>
        <predecessor elementType="road" elementId="2" />
        <successor elementType="road" elementId="3" />
</link>
```

3. Define the road geometry:

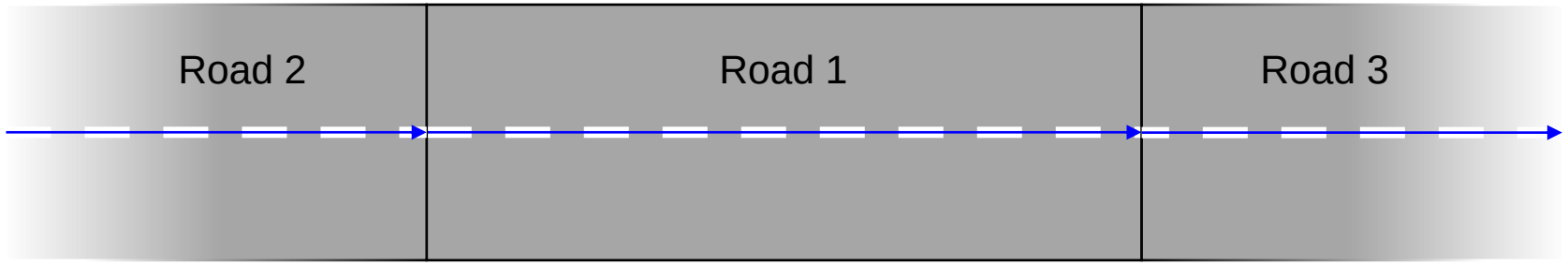
```
<geometry s="0.0e+00" x="0.0e+00" y="0.0e+00" hdg="0.0e+00" length="1.0e+02">
        <line/>
</geometry>
```

Road Definition

4. Define the lanes

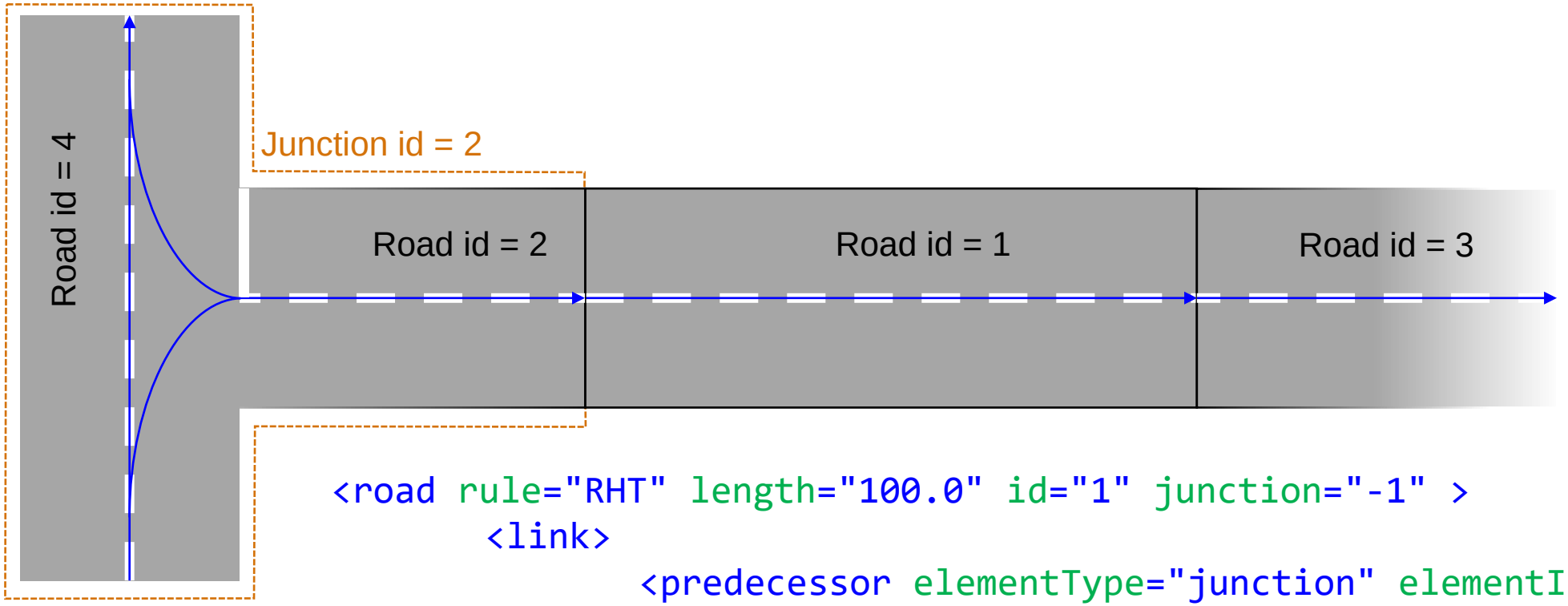
```
<lane id="1" type="driving" level="false">
    <link>
        <successor id="1" predecessor id="1" />
    </link>
    <border sOffset="0.0" a="3.569" b="0.0" c="0.0" d="0.0"/>
    <roadMark sOffset="0.0" type="broken" weight="standard" color="standard"
              width="1.2e-01" laneChange="none" height="1.99e-02">
        <type name="broken" width="1.2e-01">
            <line length="0.0e+00" space="0.0" tOffset="0.0" sOffset="0.0"
                  rule="no passing" width="1.2"/>
        </type>
     </roadMark>
</lane>
```

ASAM OpenDRIVE: Road Definition



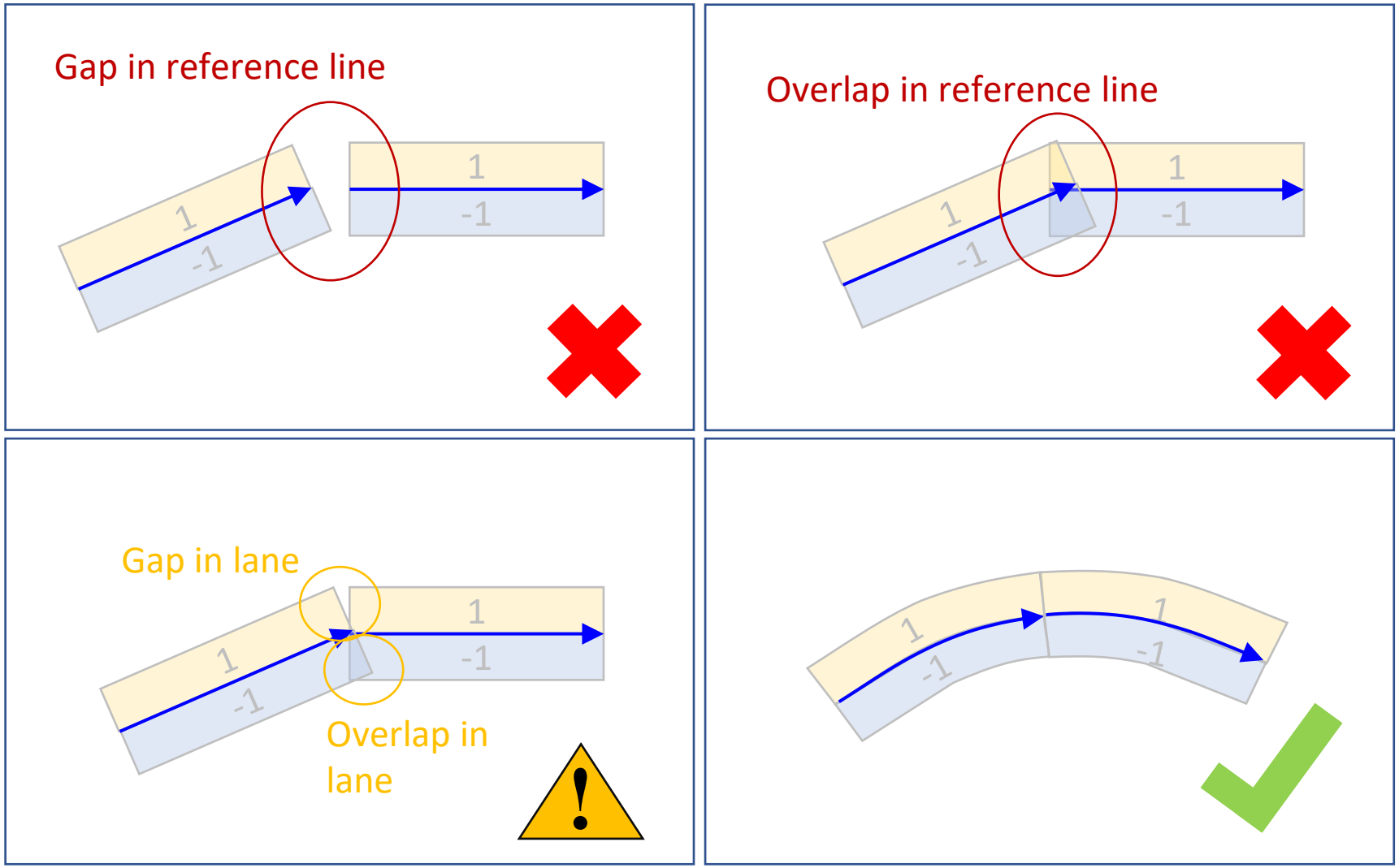

```
<road rule="RHT" name= "example_road" length="1.00e+02" id="1" junction="-1">
     <link>
          <predecessor elementType="road" elementId="2" />
          <successor elementType="road" elementId="3" />
     </link>
     <planView>
          <geometry s="0.0e+00" x="0.0e+00" y="0.0e+00" hdg="0.0e+00" length="1.0e+02">
                    <line/>
          </geometry>
     </planView>
     <lateralProfile></lateralProfile>
     <lanes>…</lanes>
     <objects></objects>
     <signals></signals>
     <surface></surface>
</road>
```

ASAM OpenDRIVE: Road Definition

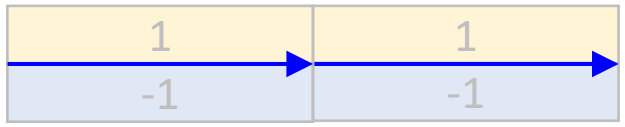



```
<road rule="RHT" length="100.0" id="1" junction="-1" >
        <link>
                <predecessor elementType="junction" elementId="2" />
                <successor elementType="road" elementId="3" />
         </link>
```

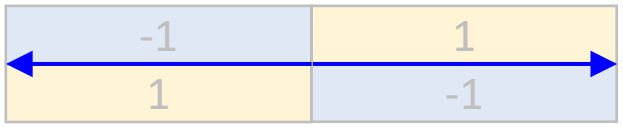
ASAM OpenDRIVE: Allowed Linkage of Roads



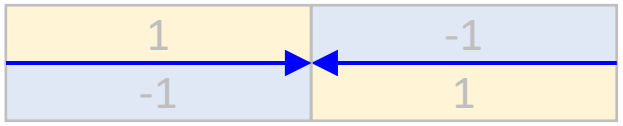
ASAM OpenDRIVE: Allowed Linkage of Roads



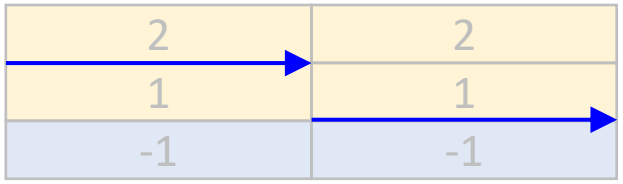
Road only,
No junctions



Road only,
No junctions

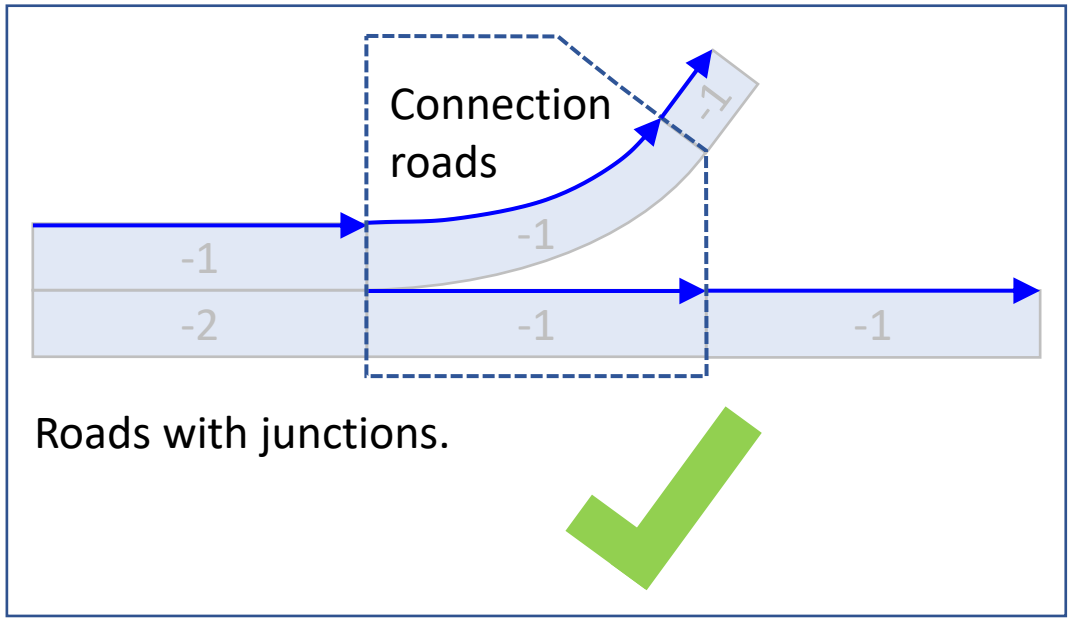


Road only,
No junctions

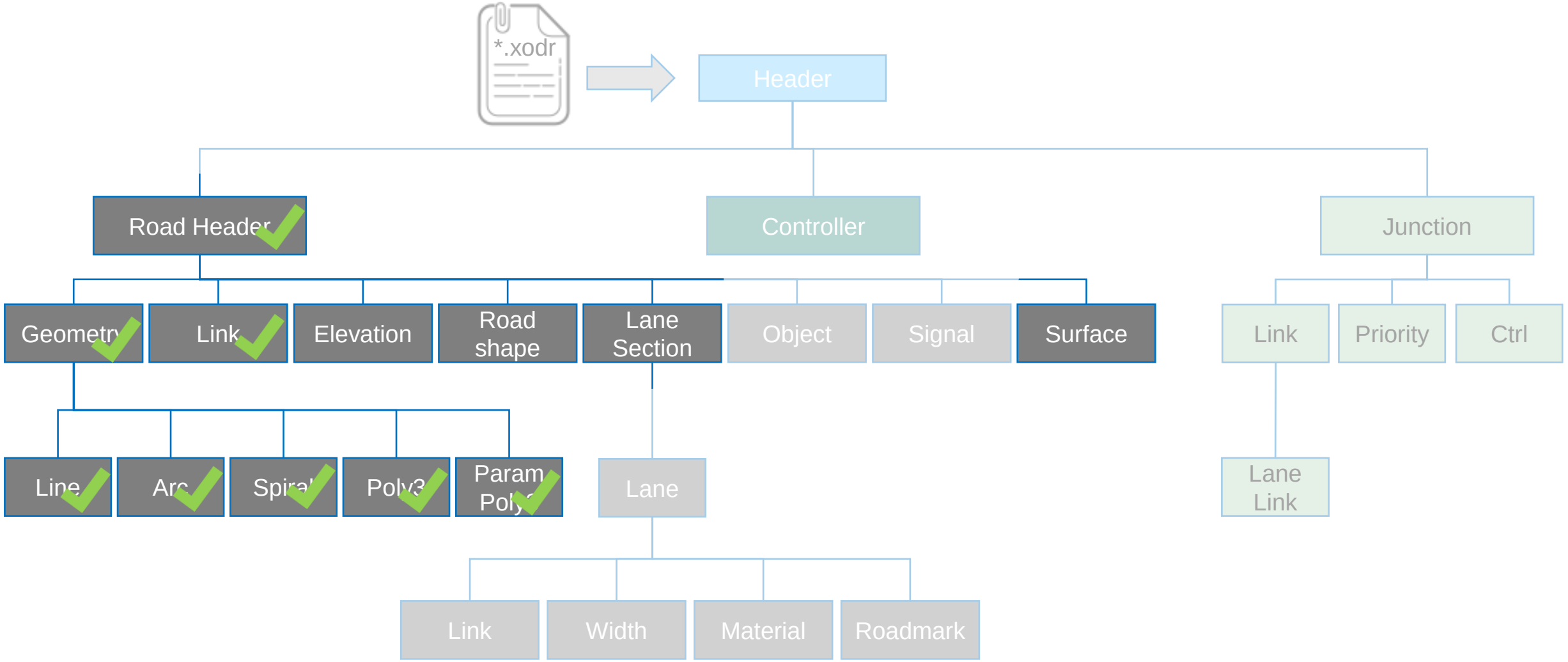


Road only,
No junctions

ASAM OpenDRIVE: Allowed Linkage of Roads

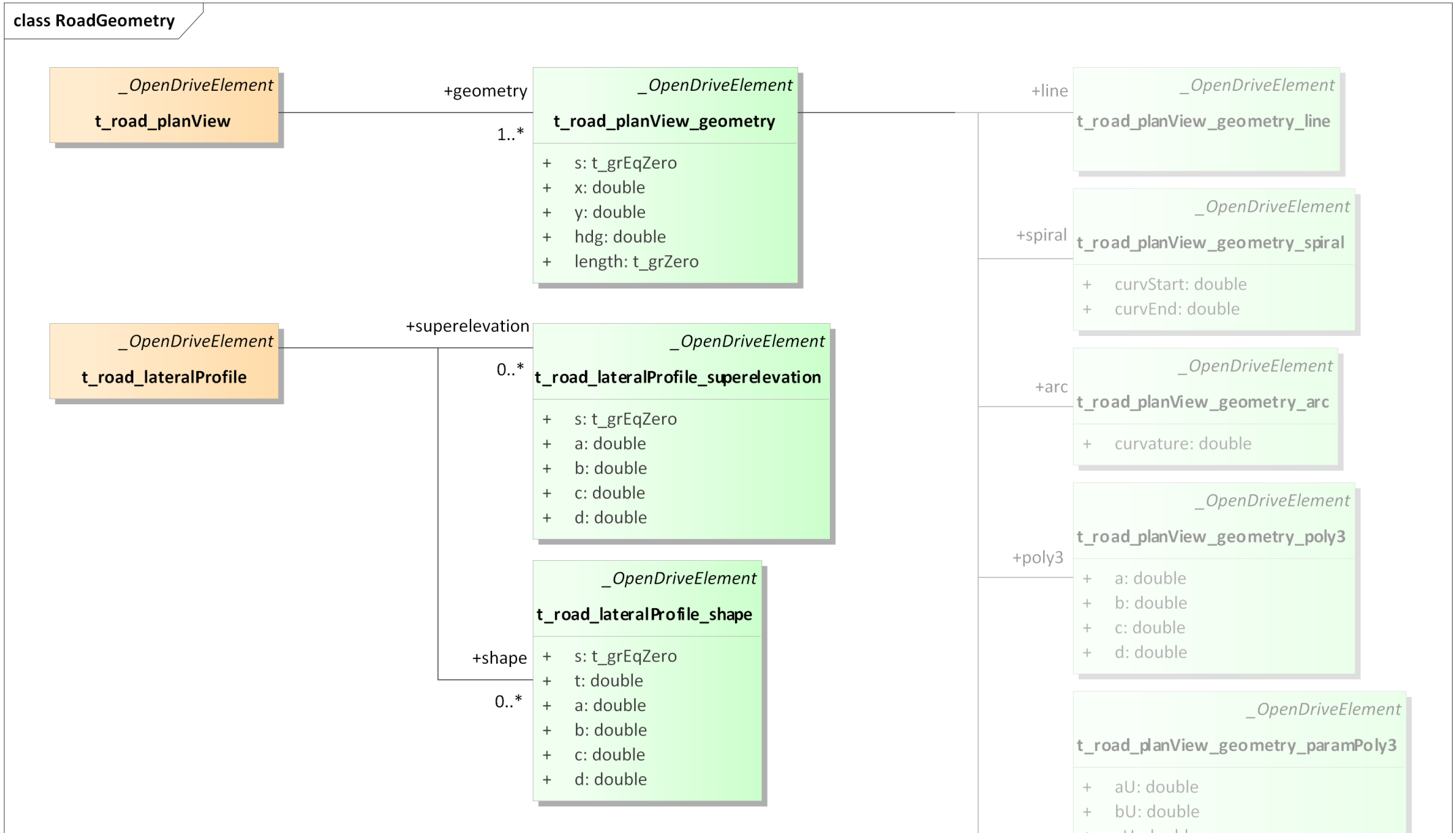


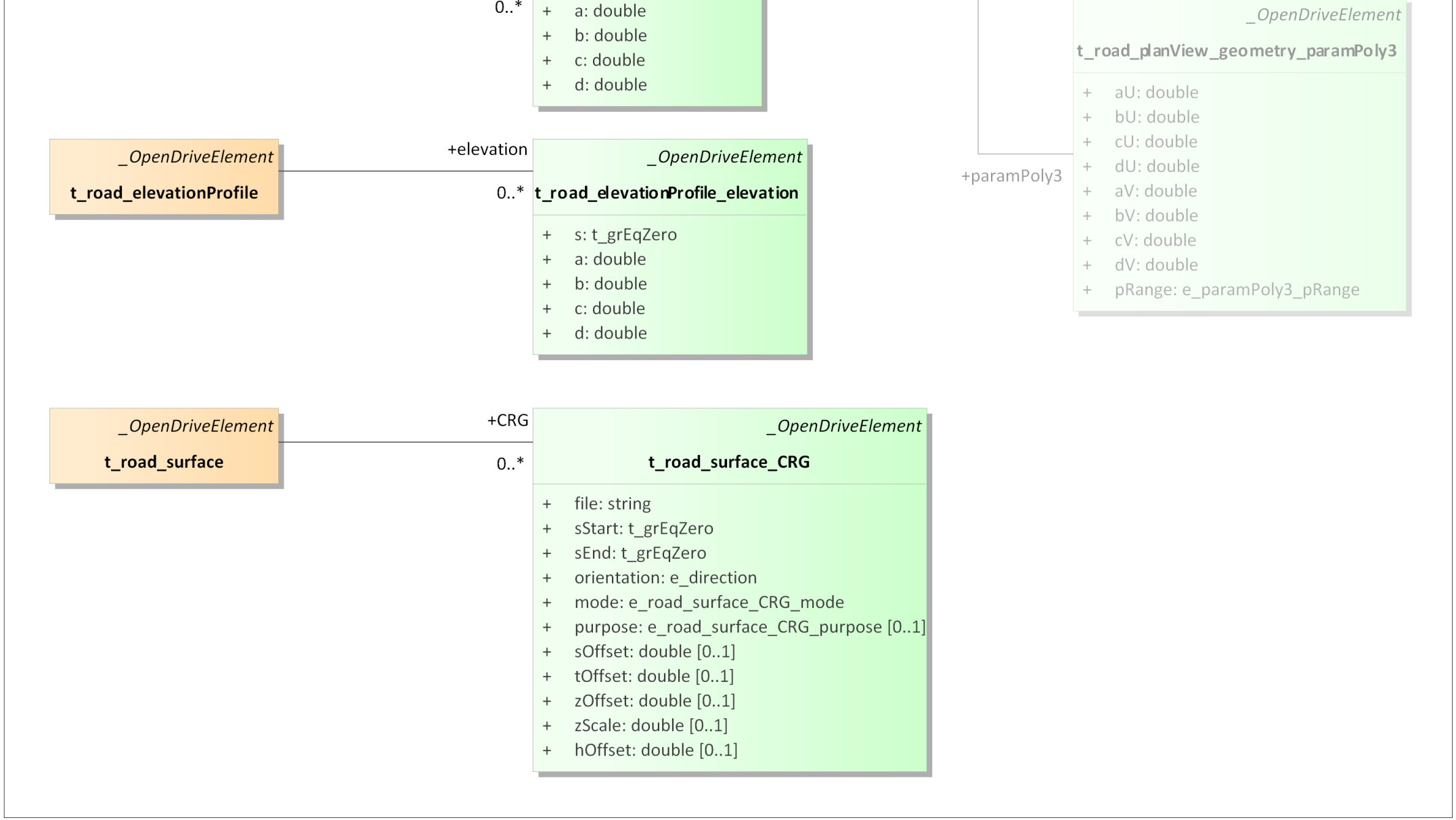
ASAM OpenDRIVE: Format



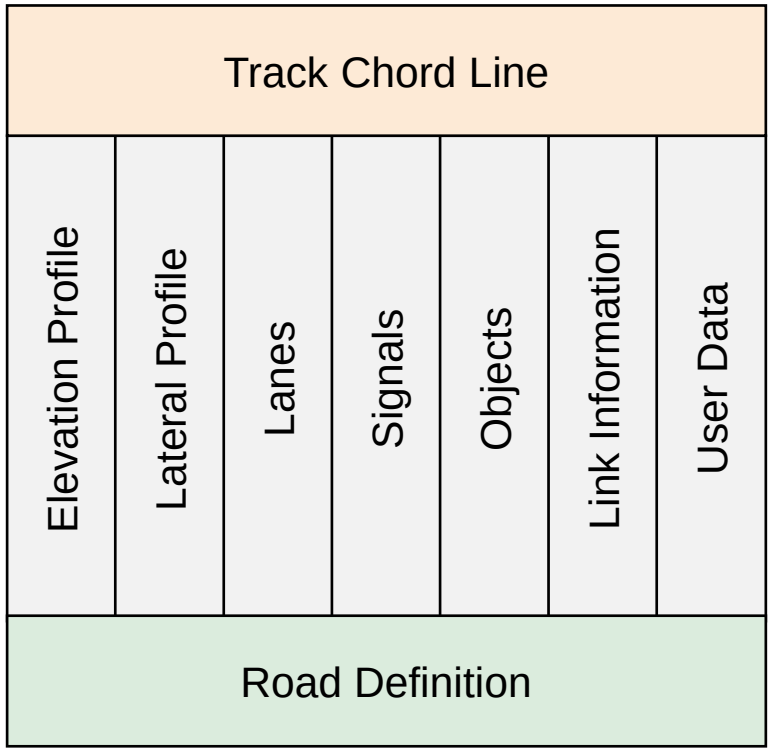
ASAM

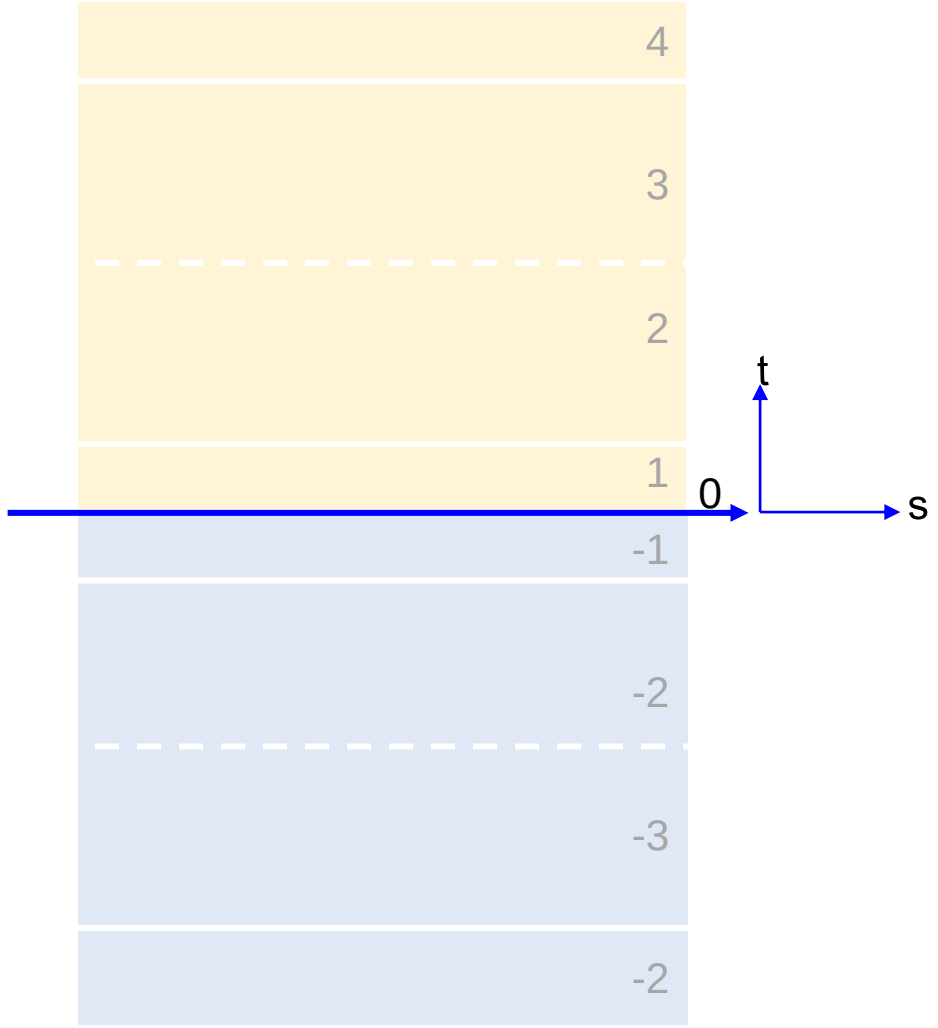
ASAM OpenDRIVE: Geometry




0..*
+ a: double
+ b: double
+ c: double
+ d: double
_OpenDriveElement
t_road_elevationProfile
+elevation
0..*
_OpenDriveElement
t_road_elevationProfile_elevation
+ s: t_grEqZero
+ a: double
+ b: double
+ c: double
+ d: double
_OpenDriveElement
t_road_surface
+CRG
0..*
_OpenDriveElement
t_road_surface_CRG
+ file: string
+ sStart: t_grEqZero
+ sEnd: t_grEqZero
+ orientation: e_direction
+ mode: e_road_surface_CRG_mode
+ purpose: e_road_surface_CRG_purpose [0..1]
+ sOffset: double [0..1]
+ tOffset: double [0..1]
+ zOffset: double [0..1]
+ zScale: double [0..1]
+ hOffset: double [0..1]
+paramPoly3
_OpenDriveElement
t_road_planView_geometry_paramPoly3
+ aU: double
+ bU: double
+ cU: double
+ dU: double
+ aV: double
+ bV: double
+ cV: double
+ dV: double
+ pRange: e_paramPoly3_pRange

ASAM OpenDRIVE: Road Features

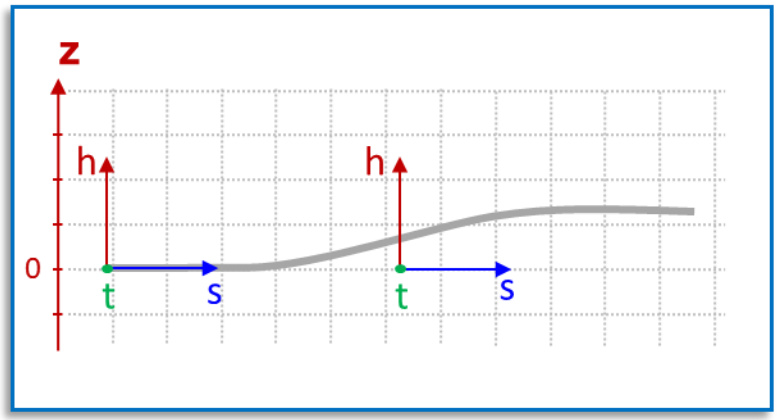




ASAM OpenDRIVE: Elevation

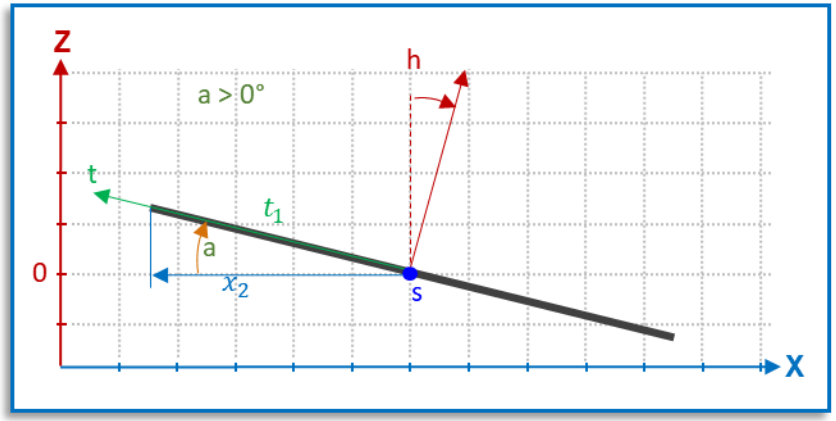
There are three ways to elevate a road or parts of a road: *Road elevation specifies the elevation along the road reference line,* that is in s-direction. The lateral profile, using *superelevation* and *shape definition, specifies the elevation orthogonally to the reference line, that is in t-direction*.

Road Elevation



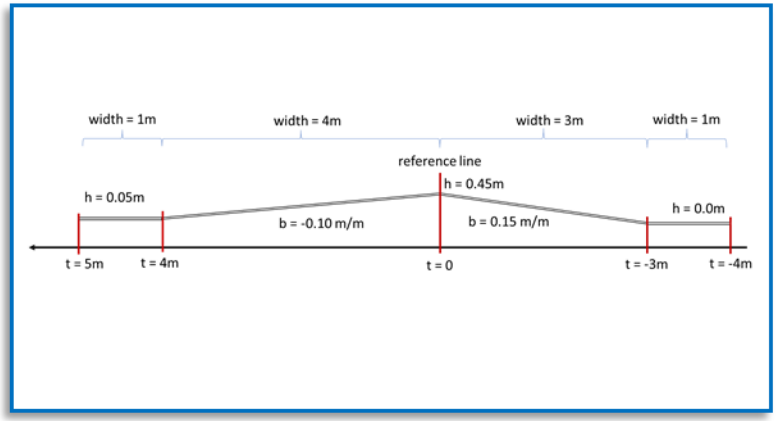
Elevation along s-axis

Super Elevation



Elevation along t-axis

Road Shape

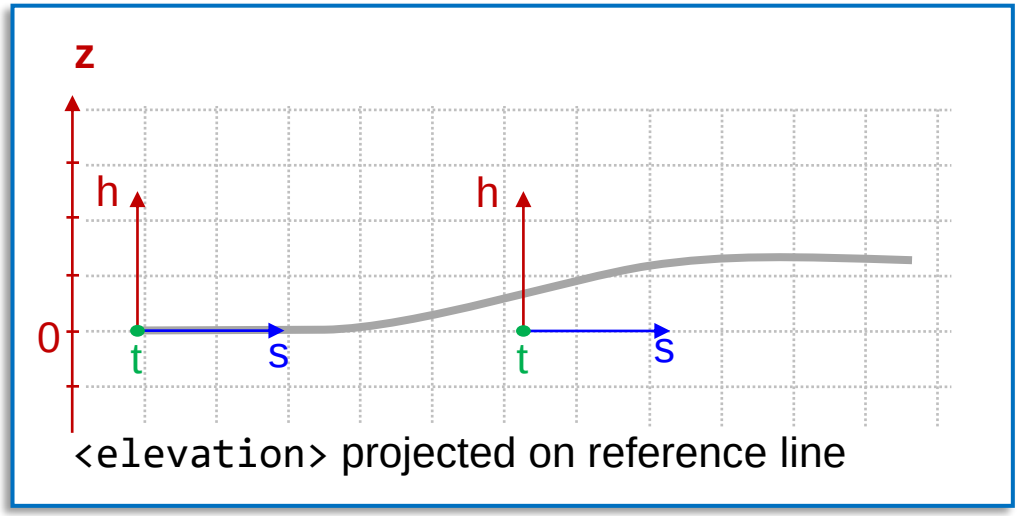


Elevation along t-axis

ASAM OpenDRIVE: Road Elevation

Formular:

$$elevation = a + b * \Delta s + c * \Delta s^2 + d * \Delta s^3$$

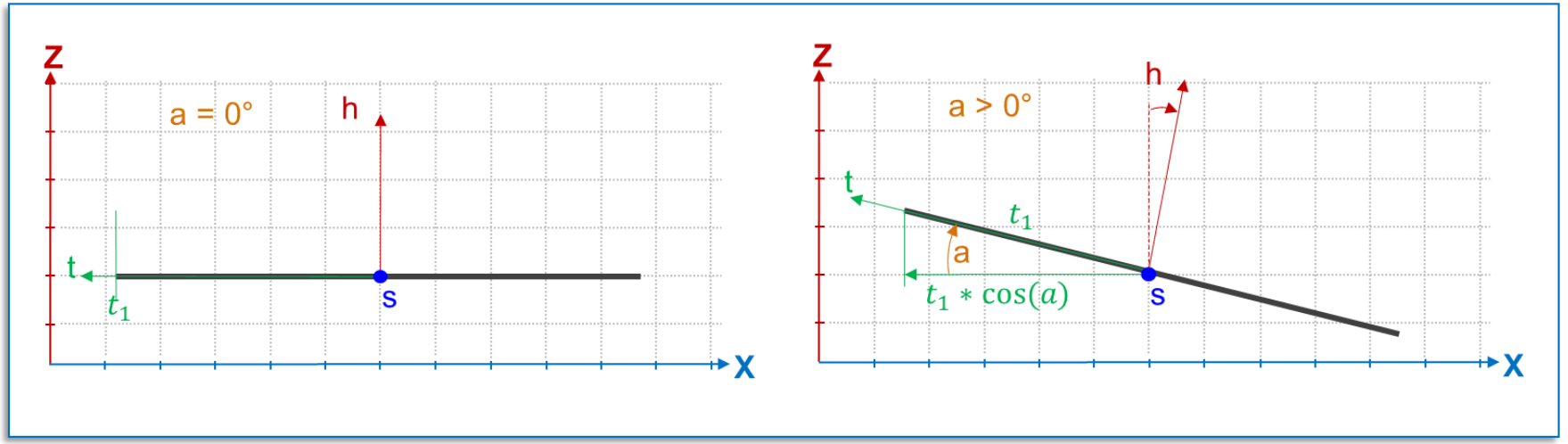


<elevation> projected on reference line

delimiters: <elevationProfile…/>
parent: <elevation>
instances: 0+
attributes:

name	*type*	*unit*	*value*	*description*
s	double	m	$[0, \infty[$	Start position (s-coordinate)
t	double	m	$]-\infty, \infty[$	Start position (t-coordinate)
a	double	m	$]-\infty, \infty[$	Parameter „a“, relative height at t=0
b	double	1	$]-\infty, \infty[$	Parameter „b“
c	double	1/m	$]-\infty, \infty[$	Parameter „c“
d	double	1/m²	$]-\infty, \infty[$	Parameter „d“

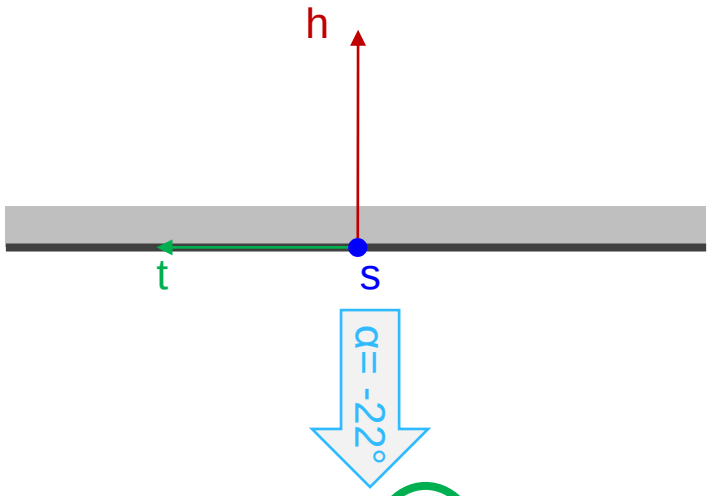
ASAM OpenDRIVE: Super Elevation



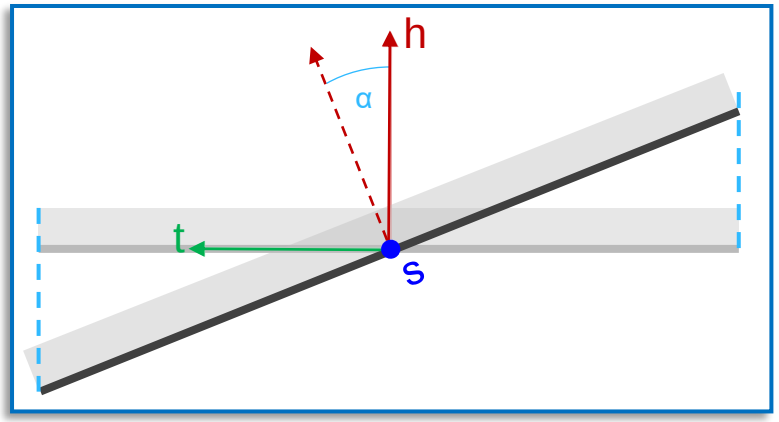
delimiters: <superelevation…/>
parent: <lateralProfile>
instances: 0+
attributes:

name	*type*	*unit*	*value*	*description*
s	double	m	$[0, \infty[$	Start position (s-coordinate)
t	double	m	$]-\infty, \infty[$	Start position (t-coordinate)
a	double	rad	$]-\infty, \infty[$	Parameter „a“, Angle!
b	double	1	$]-\infty, \infty[$	Parameter „b“
c	double	1/m	$]-\infty, \infty[$	Parameter „c“
d	double	1/m²	$]-\infty, \infty[$	Parameter „d“

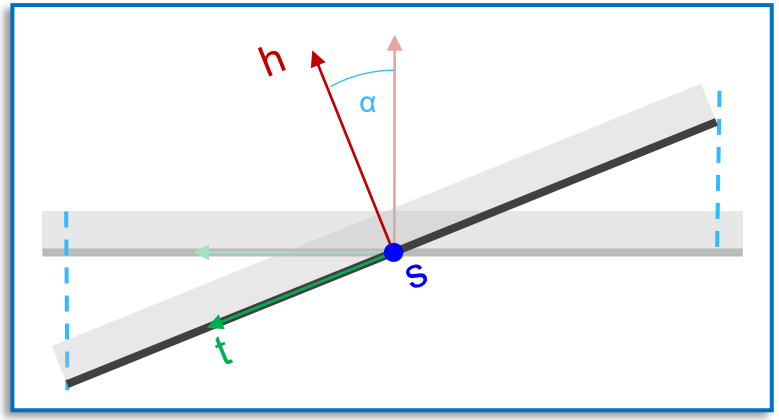
ASAM OpenDRIVE: Super Elevation



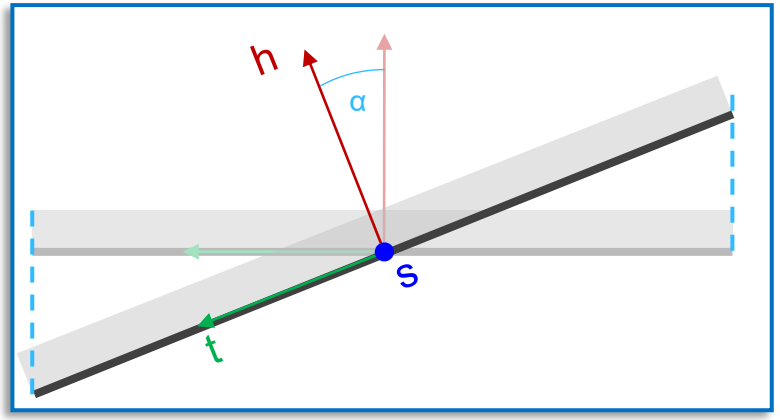
1



2



3



ASAM

ASAM OpenDRIVE: Lateral Profile 1/2

Formular to calculate shape:

$$h_{Shape} = a + b * \Delta t + c * \Delta t^2 + d * \Delta t^3$$

Coefficients in formula:

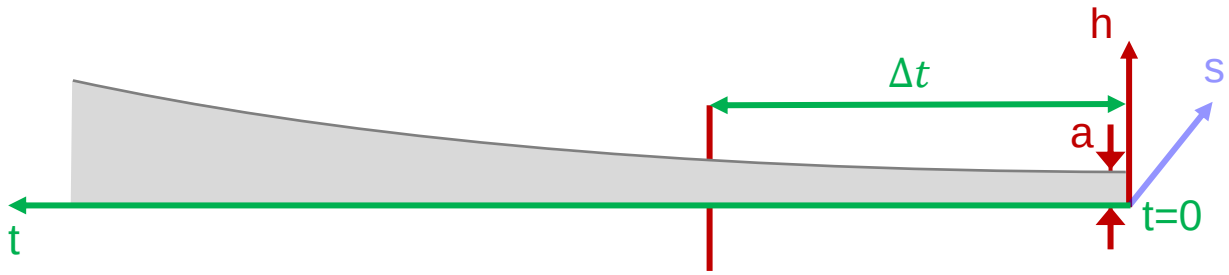
h_{Shape}: being the height above the reference plane at a given position, default h= 0

a, b, c, d: coefficients of the 3rd order polynomial

Δt: being the distance perpendicular to the reference line between the start of the entry and the actual position

Therefore Δt starts at zero for each entry. The absolute position of the shape value is calculated by:

$$t = t_{Start} + \Delta t$$



Coefficients in formula:

t: the absolute position (reference-line coordinate system)

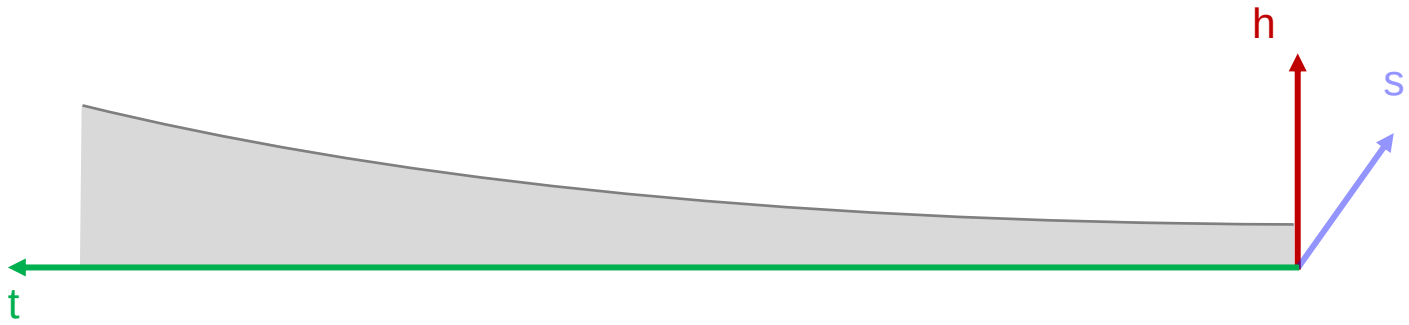
t_{Start}: start position of the entry in the reference-line coordinate system

Δt: the delta between the start position and the requested position

ASAM OpenDRIVE: Lateral Profile 2/2

Formular to calculate shape:

$$h_{Shape} = a + b * \Delta t + c * \Delta t^2 + d * \Delta t^3$$

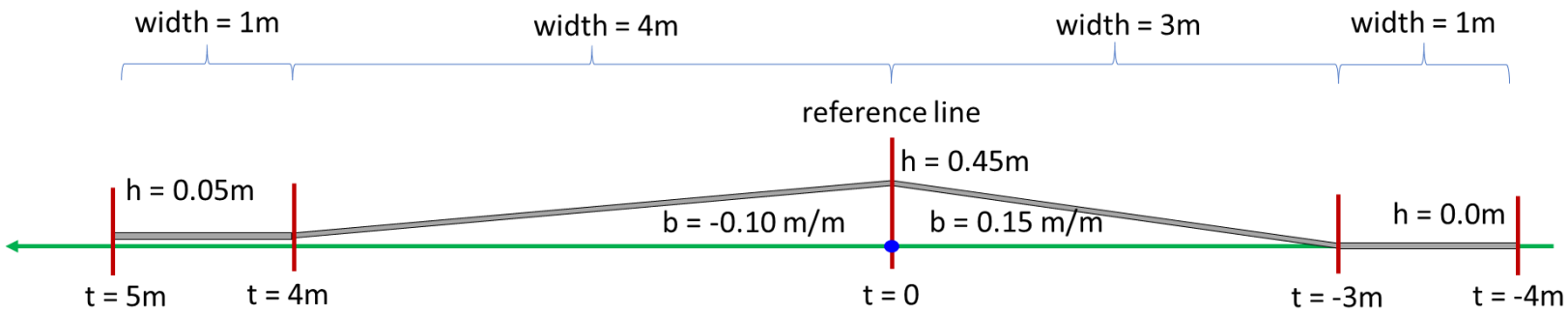


delimiters: <shape…/>
parent: <lateralProfile>
instances: 0+
attributes:

name	*type*	*unit*	*value*	*description*
s	double	m	[0, ∞[	Start position (s-coordinate)
t	double	m	] – ∞, ∞[	Start position (t-coordinate)
a	double	m	] – ∞, ∞[	Parameter „a“, relative height at t=0
b	double	1	] – ∞, ∞[	Parameter „b“
c	double	1/m	] – ∞, ∞[	Parameter „c“
d	double	1/m²	] – ∞, ∞[	Parameter „d“

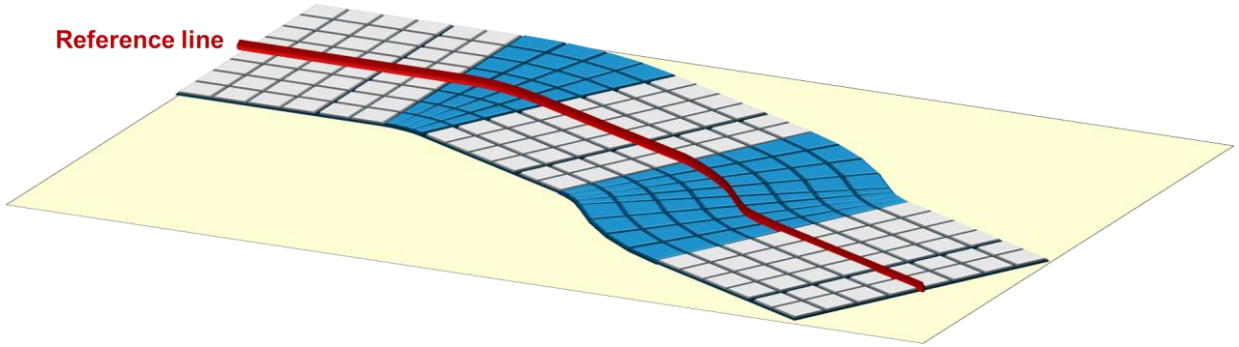
ASAM OpenDRIVE: Lateral Profile Example

```
<lateralProfile>
<shape    s="0.0000000000000000e+00"
          t="-4.0000000000000000e+00"
          a="0.0000000000000000e+00"
          b="0.0000000000000000e+00"
          c="0.0000000000000000e+00"
          d="0.0000000000000000e+00"/>
<shape    s="0.0000000000000000e+00"
          t="-3.0000000000000000e+00"
          a="0.0000000000000000e+00"
          b="1.4999999999999999e-01"
          c="0.0000000000000000e+00"
          d="0.0000000000000000e+00"/>
<shape    s="0.0000000000000000e+00"
          t="0.0000000000000000e+00"
          a="4.5000000000000001e-01"
          b="-1.0000000000000001e-01"
          c="0.0000000000000000e+00"
          d="0.0000000000000000e+00"/>
<shape    s="0.0000000000000000e+00"
          t="4.0000000000000000e+00"
          a="5.0000000000000003e-02"
          b="0.0000000000000000e+00"
          c="0.0000000000000000e+00"
          d="0.0000000000000000e+00"/>
</lateralProfile>
```



ASAM

ASAM OpenDRIVE: Surface



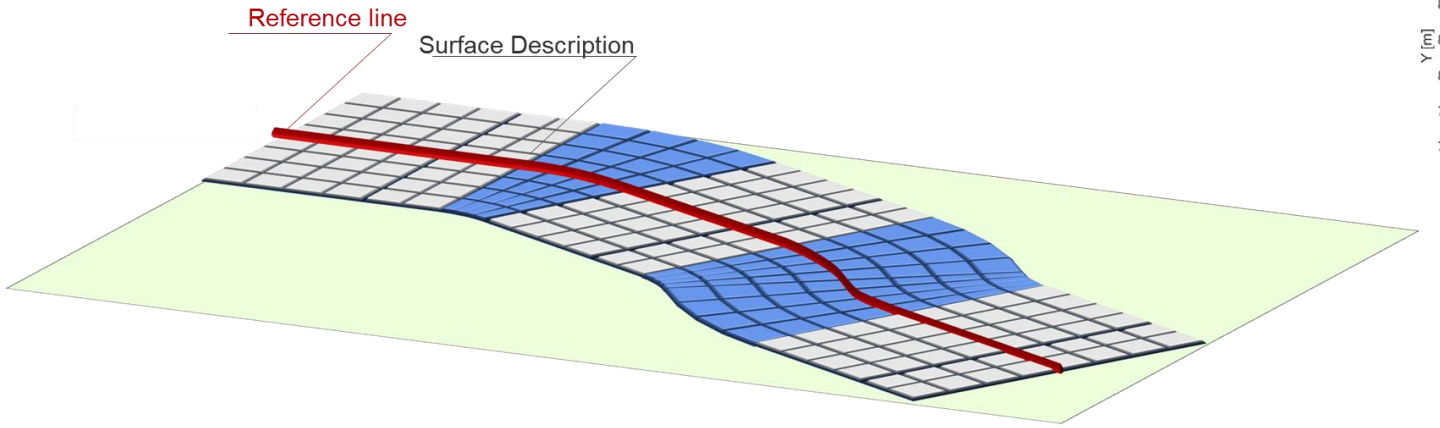
delimiters: <CRG>…</CRG>
parent: <surface>
instances: 0+
attributes:

name	*type*	*unit*	*value*	*description*
file	string	-	-	name of the file containing the CRG data
sStart	double	m	$[0, \infty[$	start of the application of CRG data (s-position)
sEnd	double	m	$[0, \infty[$	end of the application of CRG data (s-position)
orientation	string	-	same, opposite	orientation of the CRG data set relative to the underlying road
mode	string	-	attached, attached0, genuine	Application mode for the surface data
purpose	string	-	elevation, friction	optional, physical purpose of the data contained in the CRG file; if the attribute is missing, data will be interpreted as elevation data
sOffset	double	m	$]-\infty, \infty[$	S-offset between CRG centerline and OpenDRIVE centerline

Introduction to OpenCRG

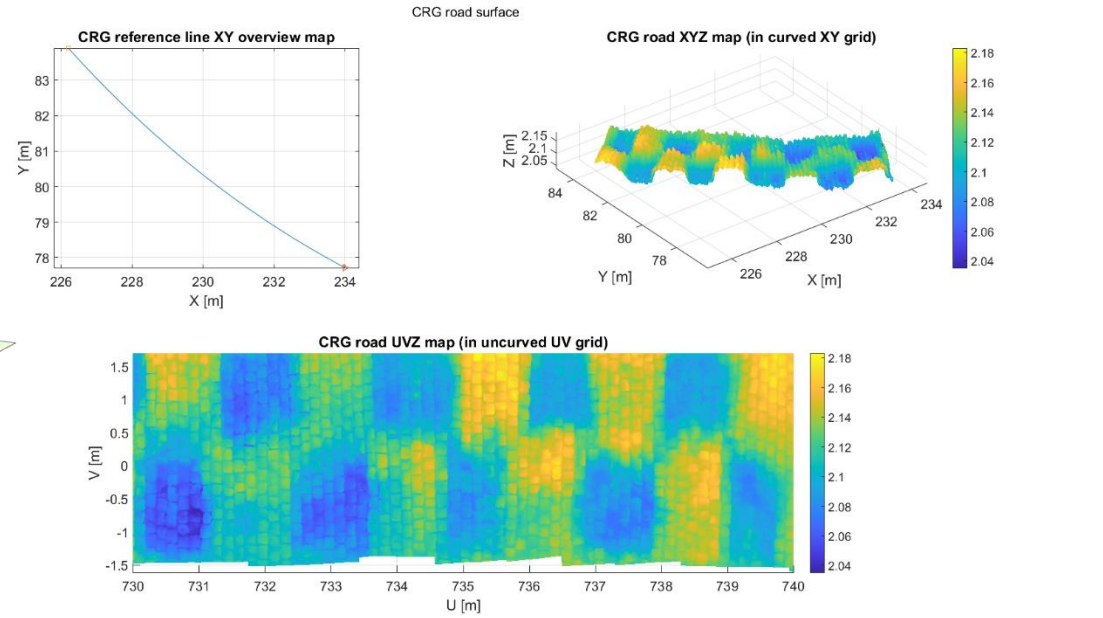
OpenCRG

- CRG = "Curved Regular Grid„
  - Developed by Daimler AG
  - open source C-API for data handling and evaluation
  - open source MATLAB® API for data manipulation and generation



Usage

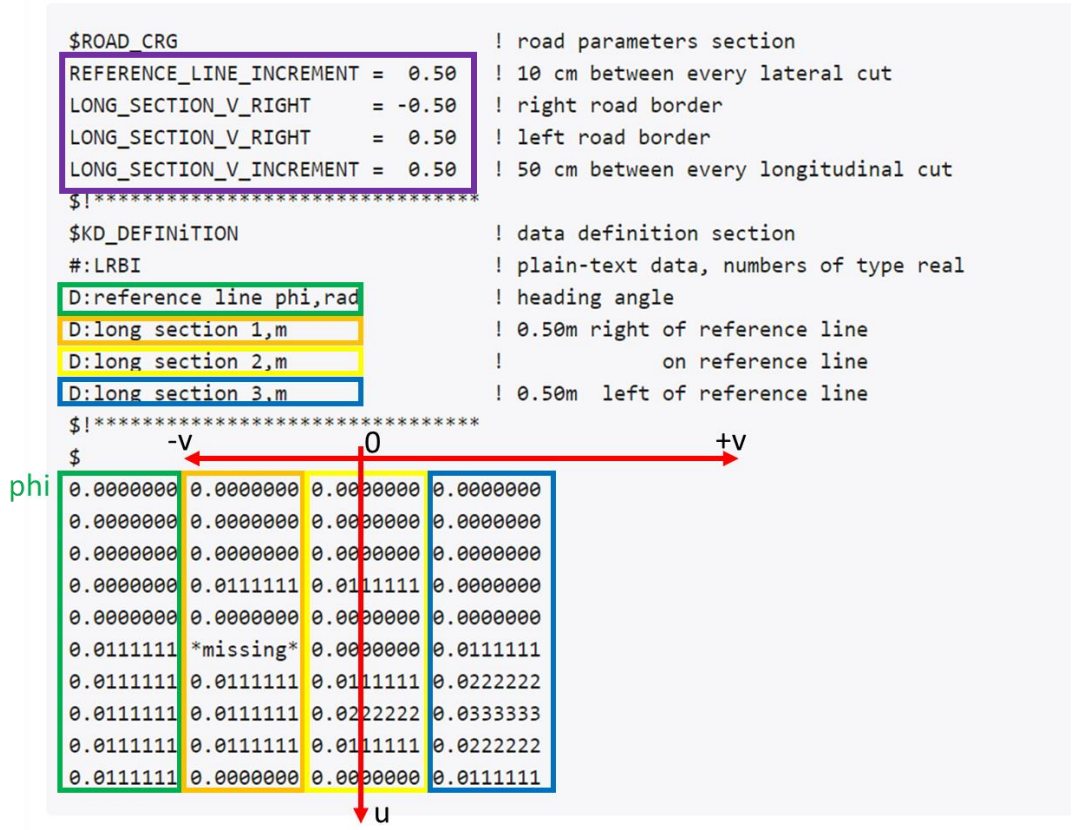
- Vehicle dynamics
- Tire simulation
- Driving simulation (Combination with OpenDRIVE !)
- Vibration simulation



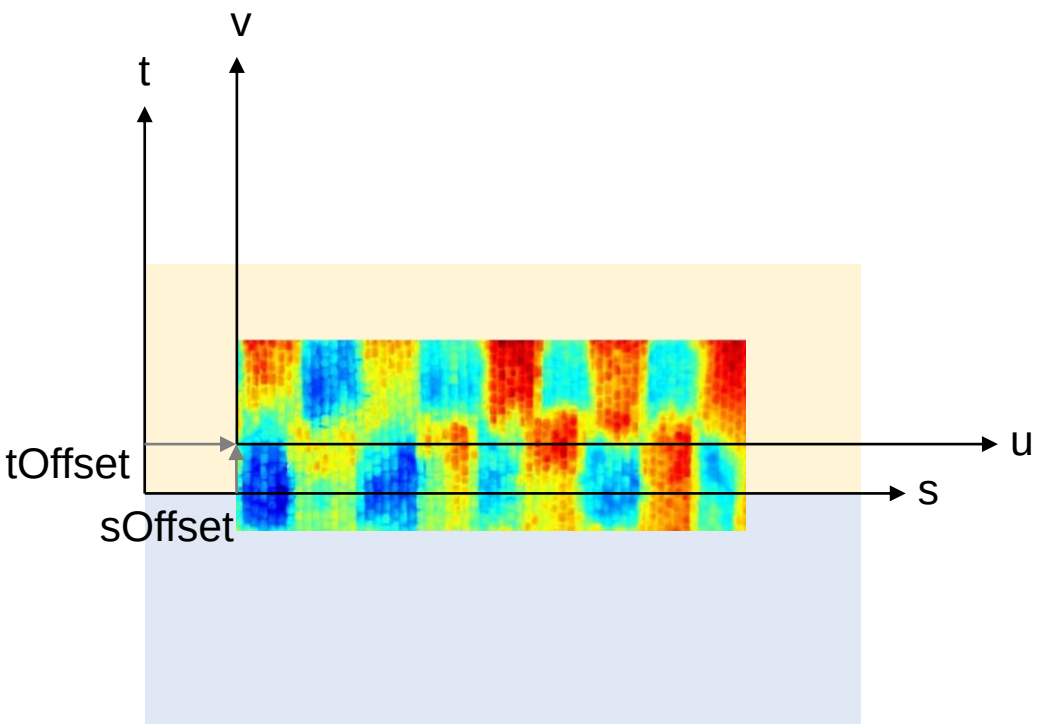
File Format OpenCRG

The OpenCRG File Format looks like the following:

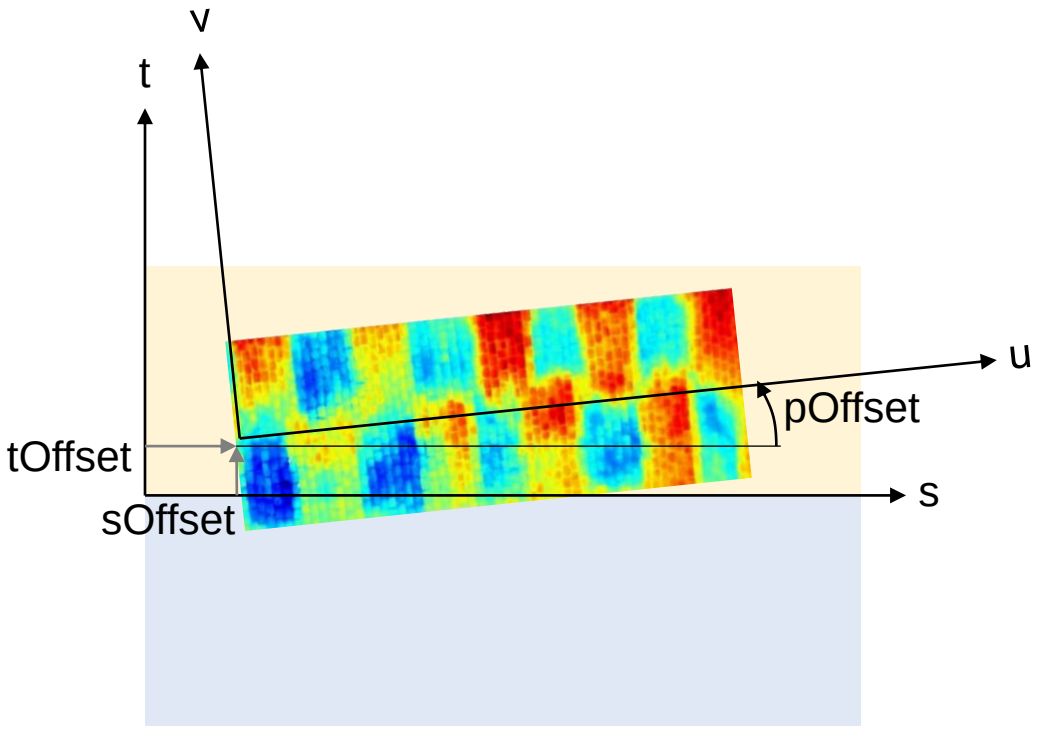
- The dimensons of the sections is defined on the top
- Options for the road sections are defind in the green box
  - heading
  - Banking
- Each long section has an individual column



ASAM OpenDRIVE: Surface, Attachment Mode

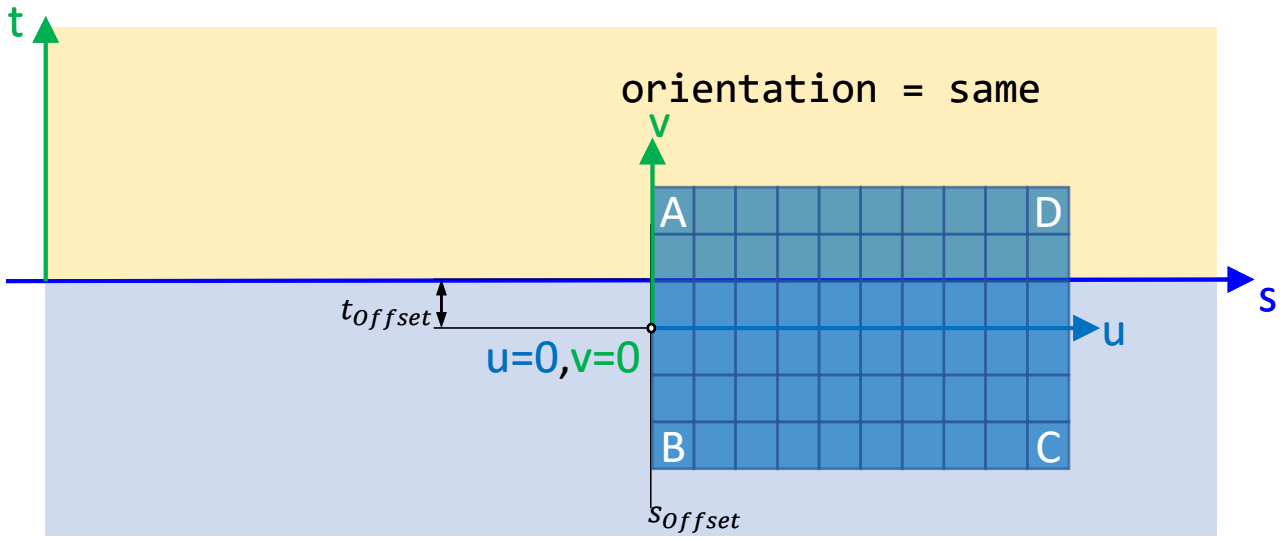


„attached“



„genuine“

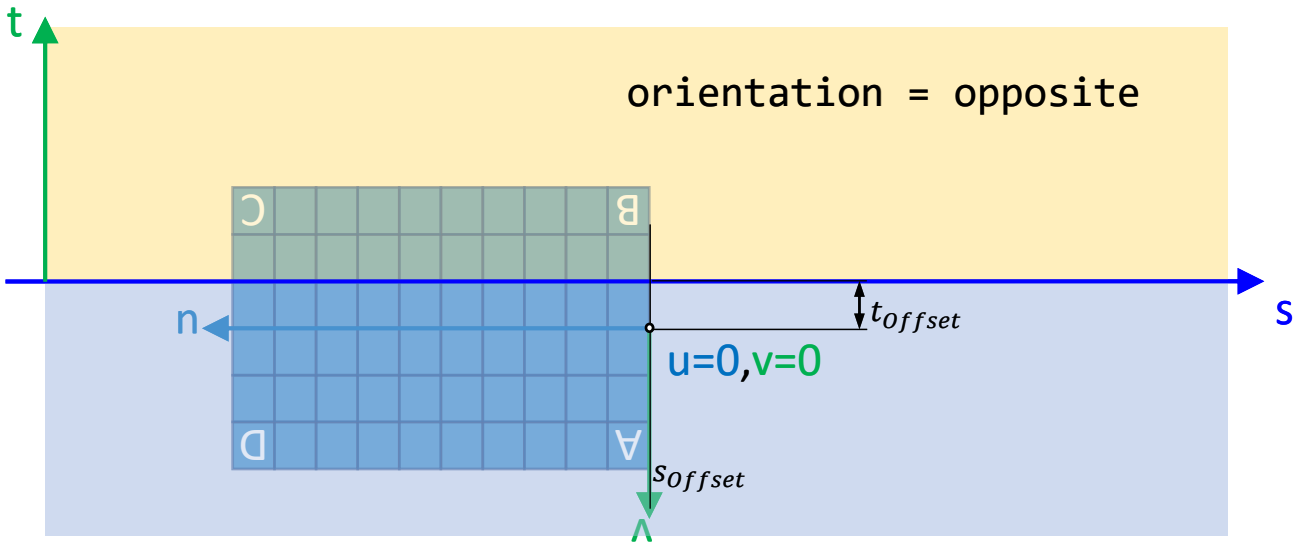
ASAM OpenDRIVE: Surface, mode = attached



orientation = same, ==> 0°

$u = s - s_{Offset}$

$v = t - t_{Offset} * \cos(0°)$ ➔ $v = t - t_{Offset} * 1$

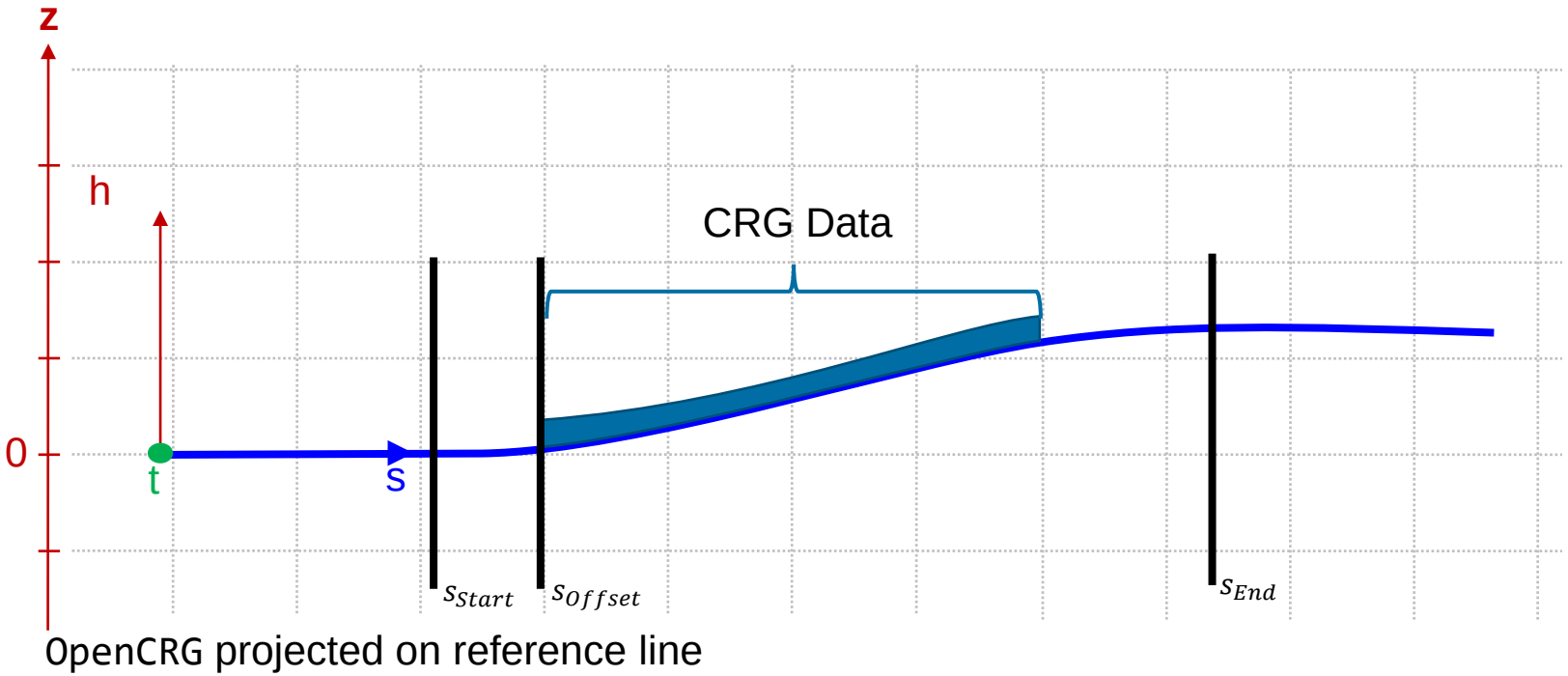


orientation = opposite, ==> 180° / π

$u = s_{Offset} - s$

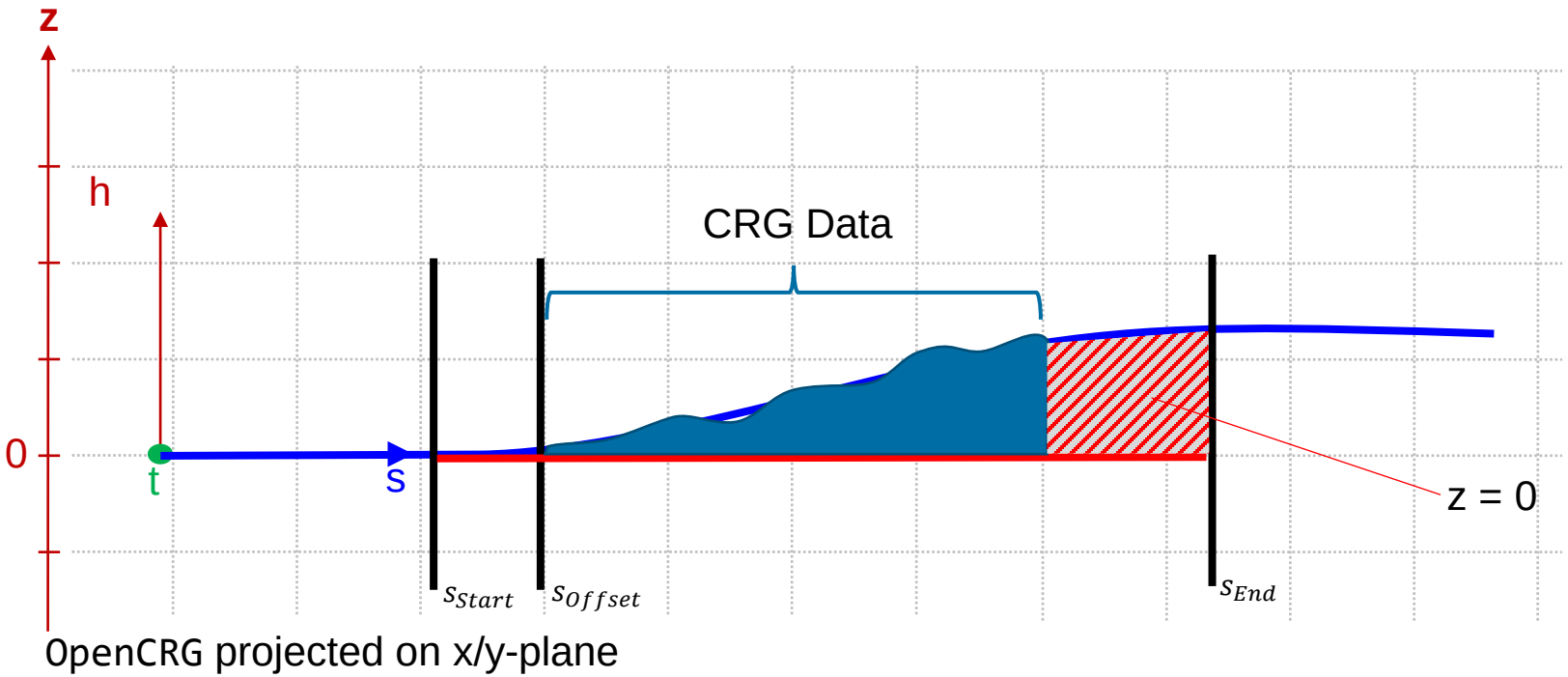
$v = t - t_{Offset} * \cos(180°)$ ➔ $v = t - t_{Offset} * -1$

ASAM OpenDRIVE: Surface, mode = attached

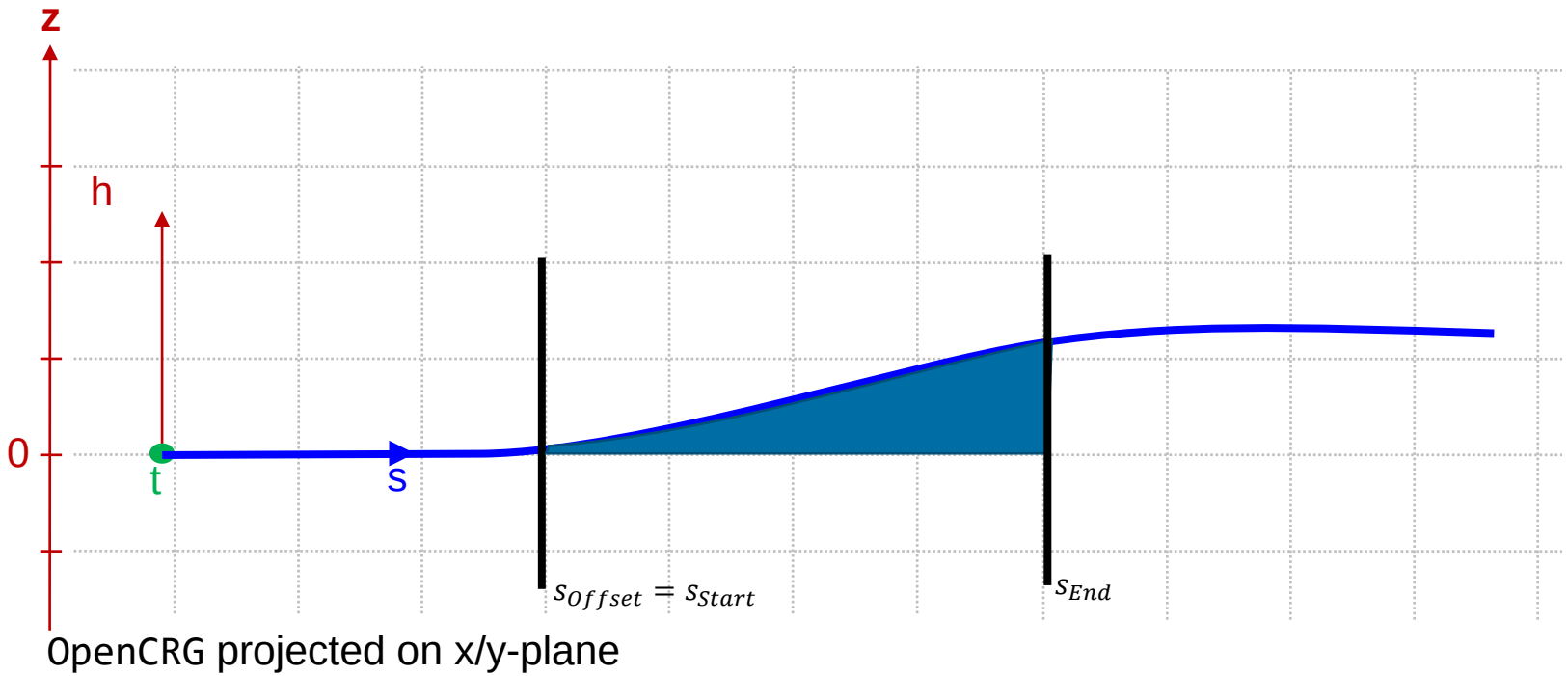


OpenCRG projected on reference line

ASAM OpenDRIVE: Surface, mode = attached0

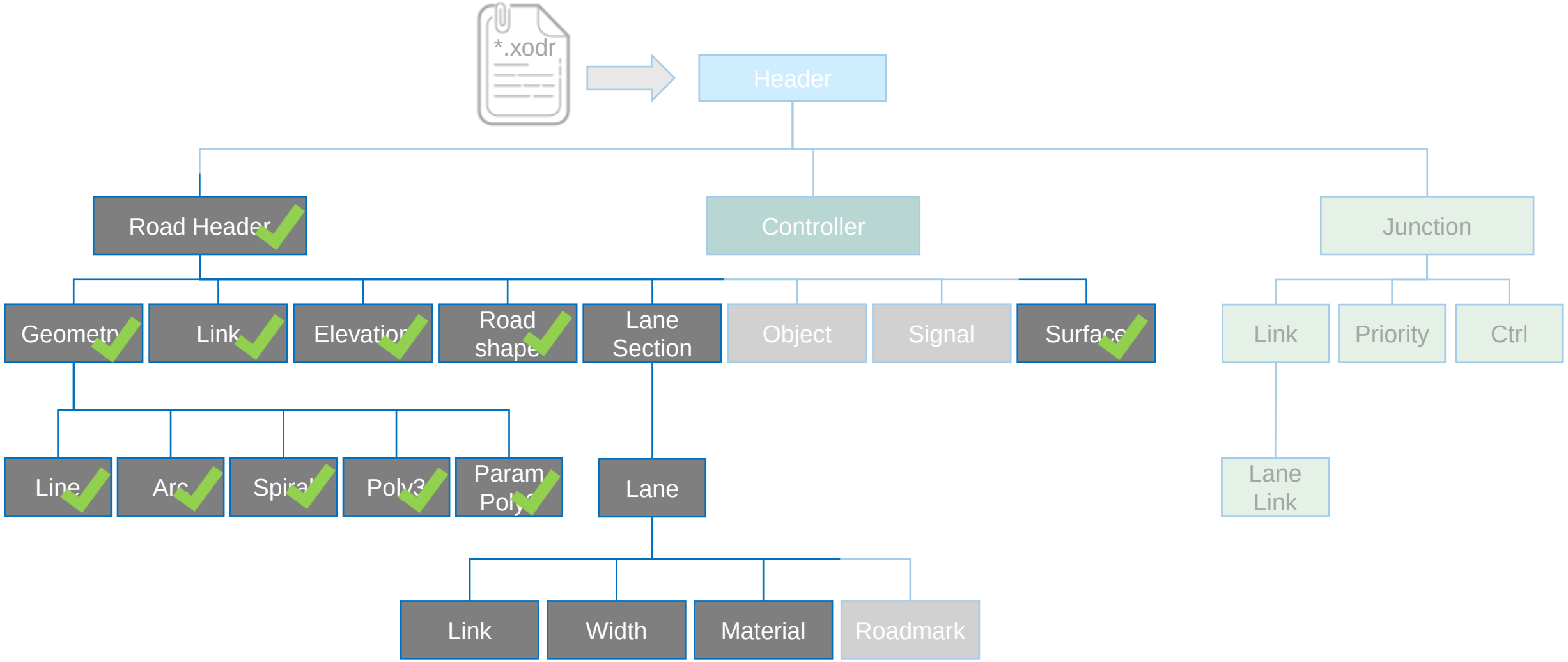


ASAM OpenDRIVE: Surface, mode = attached0



OpenCRG projected on x/y-plane

ASAM OpenDRIVE: Format



ASAM OpenDRIVE: Questions and Answers

Announcments upcoming events

- ASAM Regional Meeting North America – Online Meeting

  Day: Oct 29, 2020

  Time: 10:00 am - 1:15 pm (EDT) | 7:00 am - 10:15 am (PDT)

  Topics: ASAM OpenX projects | SOVD (Service-Oriented Vehicle Diagnostics) | Amazon Web Services: Activites in ADAS / AD

  Agenda -> Registration ->

- 1st ASAM Regional Meeting China – SAVE THE DATE

  Day: Nov 26 – 27, 2020

  Time: Nov 26: 15:00 - 18:00 (CST) | Nov 27: 9:00 - 17:00 (CST)

  Registration will open soon!

- ASAM General Assembly 2021 (Online) – SAVE THE DATE

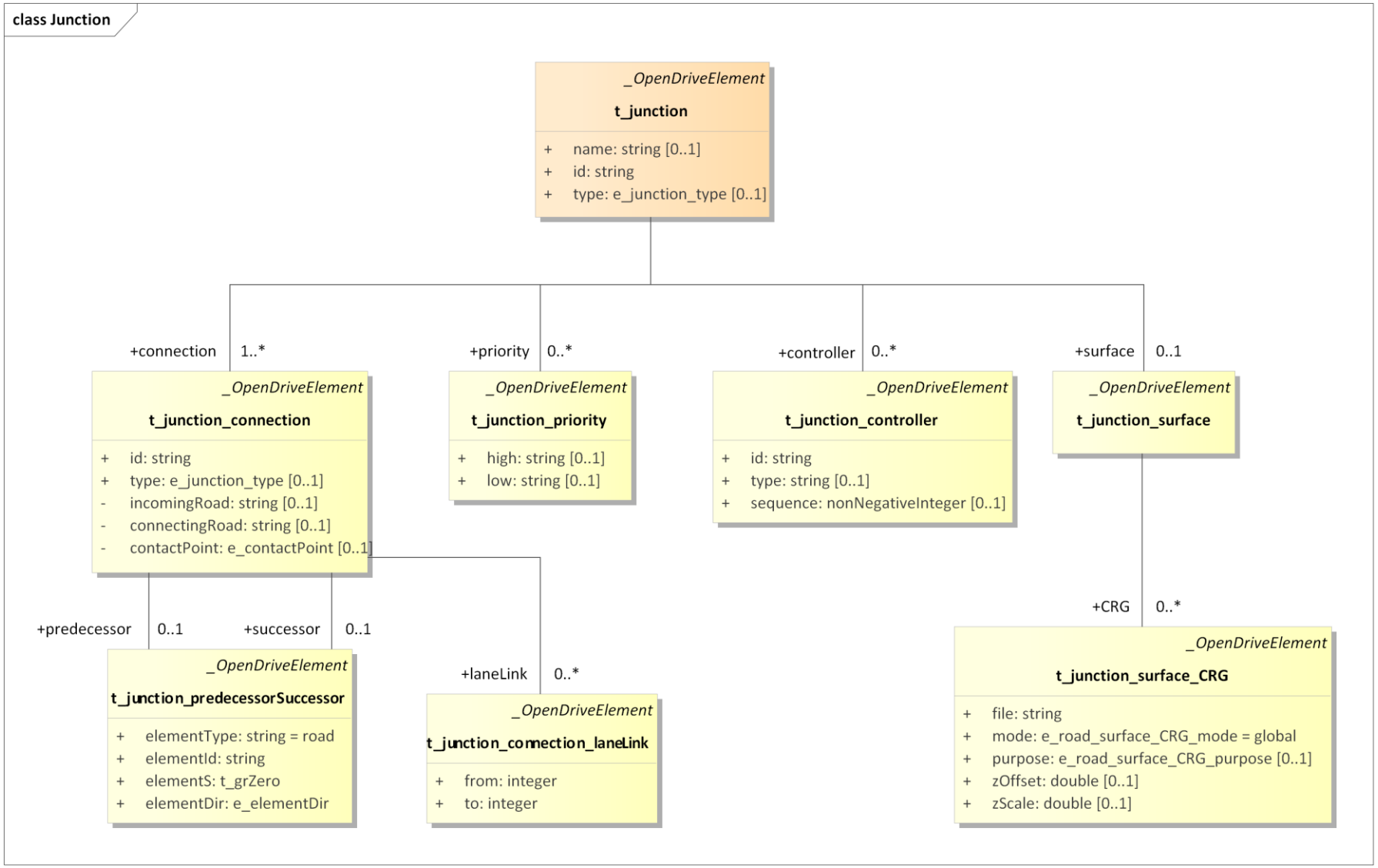
  Day: Mar 24, 2021

  Time: 09:00 – 12:00 CET

⇒ Sign up for the ASAM newsletter to be informed about upcoming webinars, projects and events
www.asam.net/newsletter

Junctions

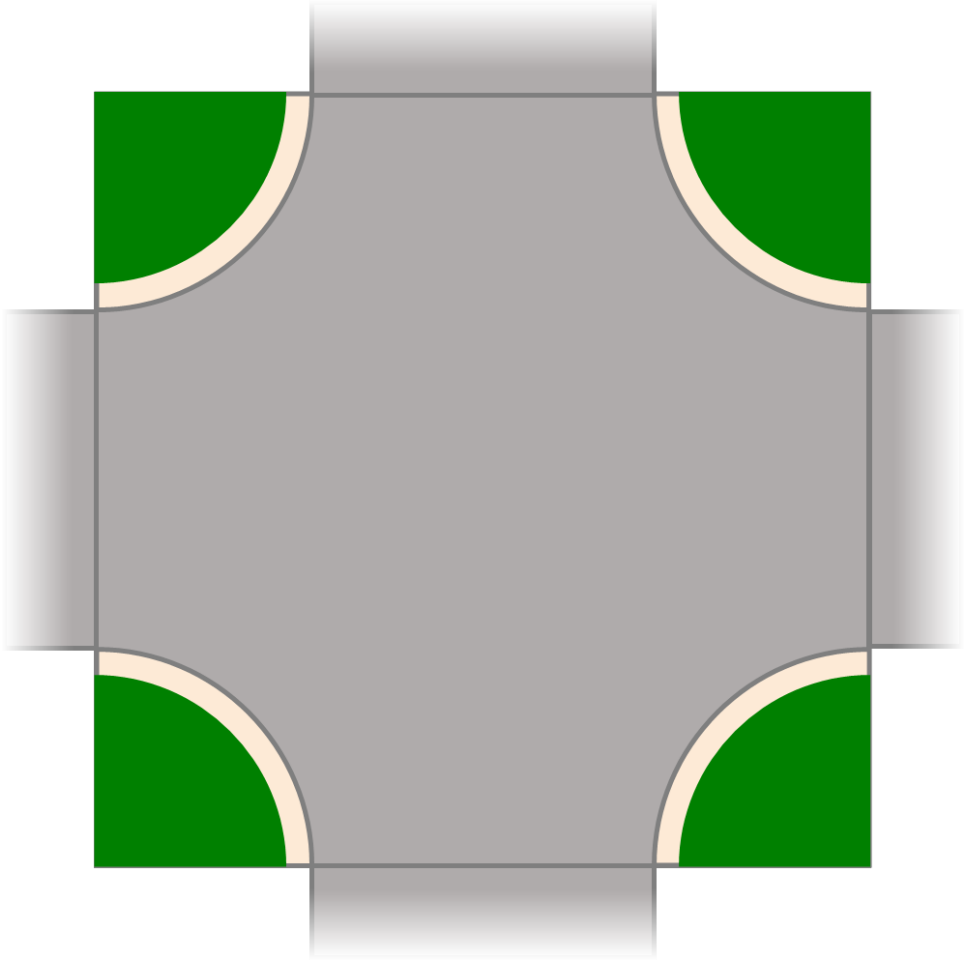
ASAM OpenDRIVE: Junctions UML Model



OpenDRIVE: Junctions

Example: Cross Junction,

- Very simple junction without traffic lights
- Right hand Traffic



ASAM OpenDRIVE: Junctions

```
<OpenDRIVE>
    <header revMajor="1" revMinor="6" name="" version="1.00" date="Mon Oct 21 13:17:23 2019"
    </header>
    <road rule="RHT" length="1.0300000000000000e+02" id="0" junction="-1" >
    <road rule="RHT" length="1.0300000000000000e+02" id="1" junction="-1">
    <road rule="RHT" length="2.8435719942688948e+01" id="2" junction="1">
    <road rule="RHT" length="2.8435719942685569e+01" id="3" junction="1">
    <road rule="RHT" length="2.9925740939669190e+01" id="4" junction="1">
    <road rule="RHT" length="2.9925740939679464e+01" id="5" junction="1">
    <road rule="RHT" length="1.0300000000000000e+02" id="6" junction="-1">
    <road rule="RHT" length="3.4000000000000000e+01" id="7" junction="1">
    <road rule="RHT" length="3.4000000000000000e+01" id="8" junction="1">
    <road rule="RHT" length="2.8435719942619844e+01" id="9" junction="1">
    <road rule="RHT" length="2.8435719942705987e+01" id="10" junction="1">
    <road rule="RHT" length="3.4000000000000000e+01" id="11" junction="1">
    <road rule="RHT" length="3.4000000000000014e+01" id="12" junction="1">
    <road rule="RHT" length="1.0300000000000000e+02" id="13" junction="-1">
    <road rule="RHT" length="2.9925740939671819e+01" id="14" junction="1">
    <road rule="RHT" length="2.9925740939663818e+01" id="15" junction="1">
    <junction name="" id="1" type="default">
        <connection id="0" incomingRoad="6" connectingRoad="2" contactPoint="start">
        <connection id="1" incomingRoad="6" connectingRoad="5" contactPoint="start">
        <connection id="2" incomingRoad="6" connectingRoad="12" contactPoint="start">
        <connection id="3" incomingRoad="0" connectingRoad="3" contactPoint="start">
        <connection id="4" incomingRoad="0" connectingRoad="8" contactPoint="start">
        <connection id="5" incomingRoad="0" connectingRoad="15" contactPoint="start">
        <connection id="6" incomingRoad="1" connectingRoad="4" contactPoint="start">
        <connection id="7" incomingRoad="1" connectingRoad="7" contactPoint="start">
        <connection id="8" incomingRoad="1" connectingRoad="10" contactPoint="start">
        <connection id="9" incomingRoad="13" connectingRoad="9" contactPoint="start">
        <connection id="10" incomingRoad="13" connectingRoad="11" contactPoint="start">
        <connection id="11" incomingRoad="13" connectingRoad="14" contactPoint="start">
    </junction>
</OpenDRIVE>
```

Define all the roads

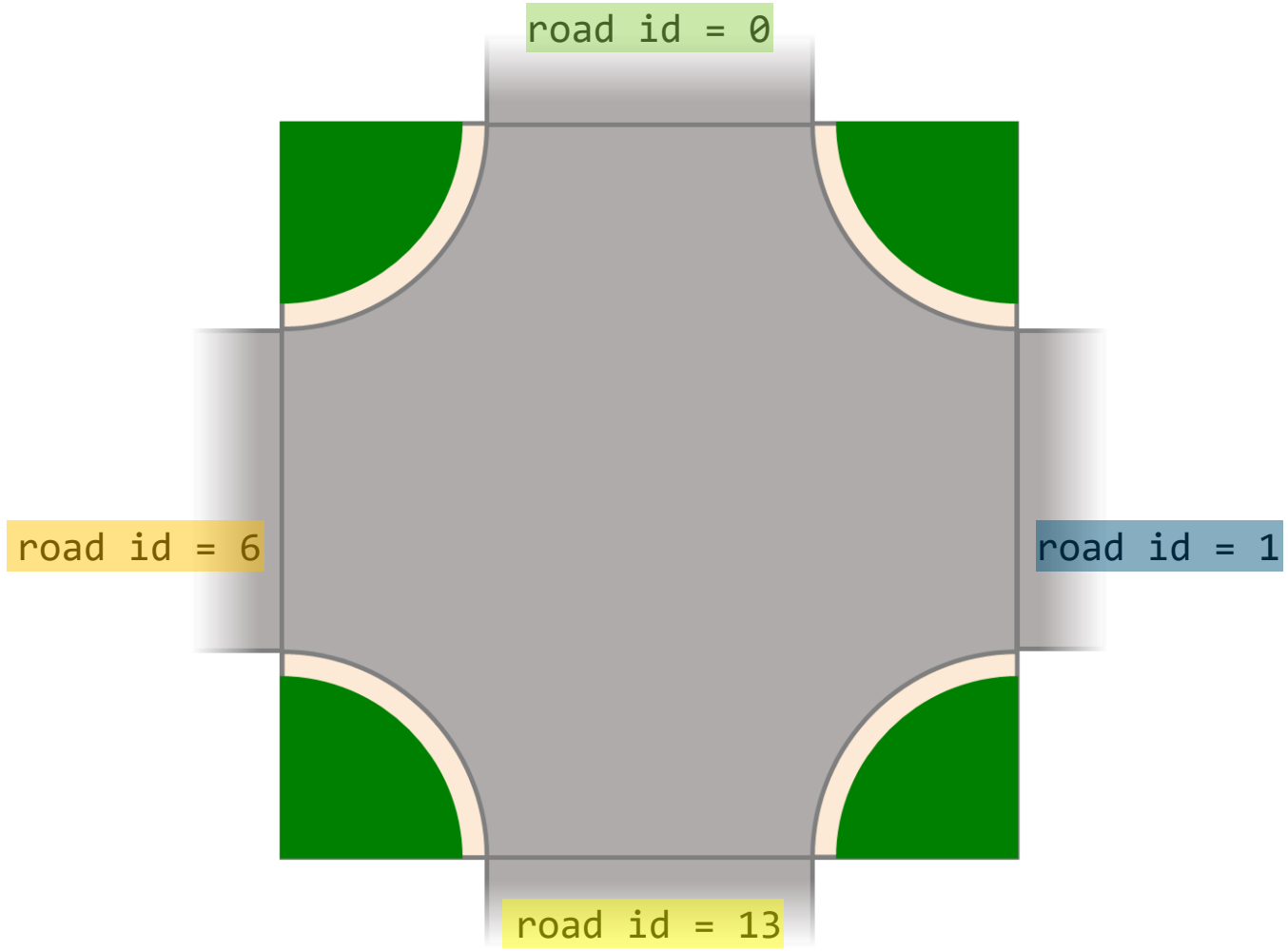
Road is part of a junction ?

Establish connections

ASAM OpenDRIVE: Junctions

Identifiy the incoming roads of a junction

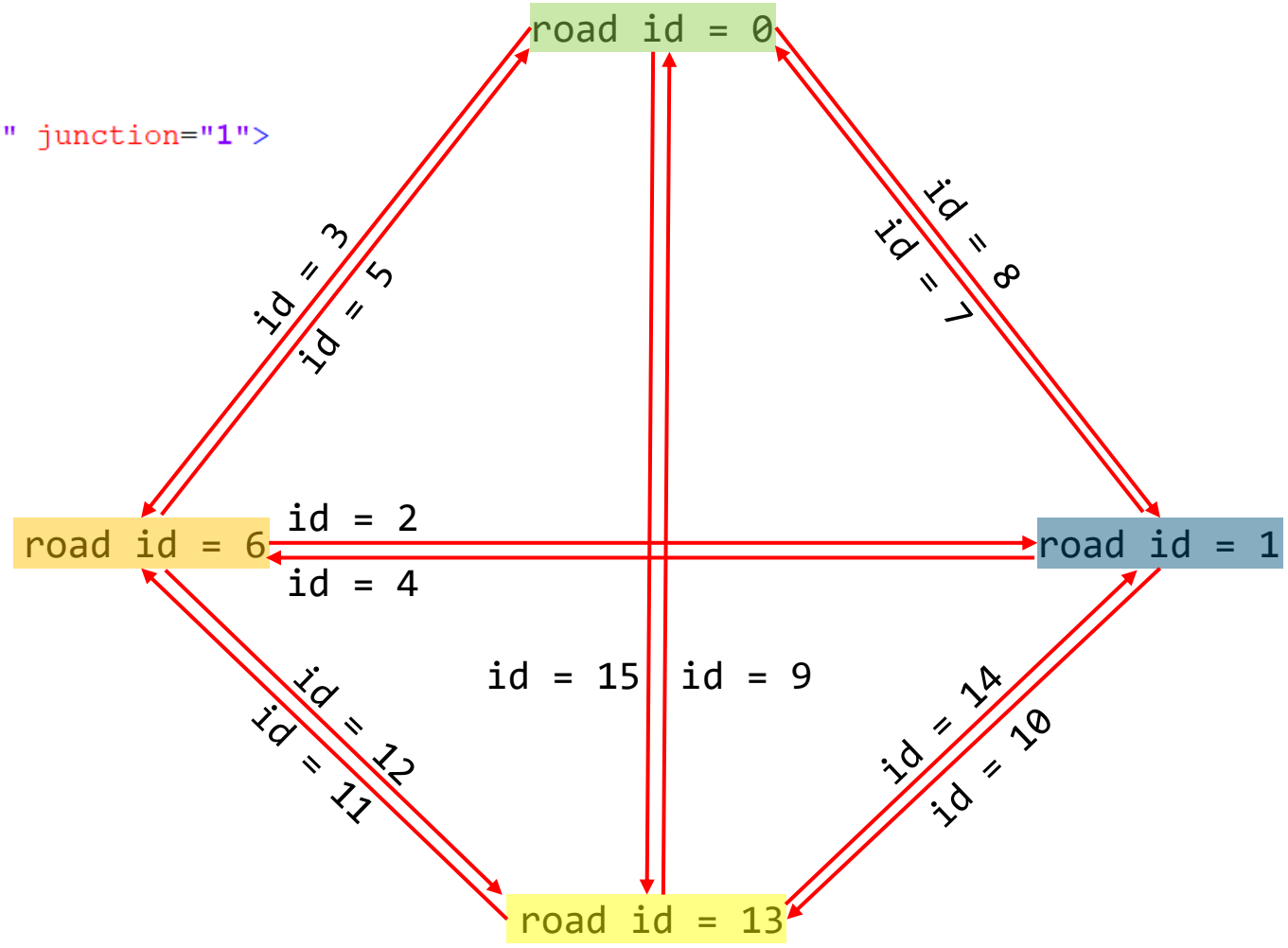
```
<junction name="" id="1" type="default">
    <connection id="0" incomingRoad="6"
    <connection id="1" incomingRoad="6"
    <connection id="2" incomingRoad="6"
    <connection id="3" incomingRoad="0"
    <connection id="4" incomingRoad="0"
    <connection id="5" incomingRoad="0"
    <connection id="6" incomingRoad="1"
    <connection id="7" incomingRoad="1"
    <connection id="8" incomingRoad="1"
    <connection id="9" incomingRoad="13"
    <connection id="10" incomingRoad="13"
    <connection id="11" incomingRoad="13"
</junction>
```



ASAM OpenDRIVE: Junctions

Identify all the connections within the junction

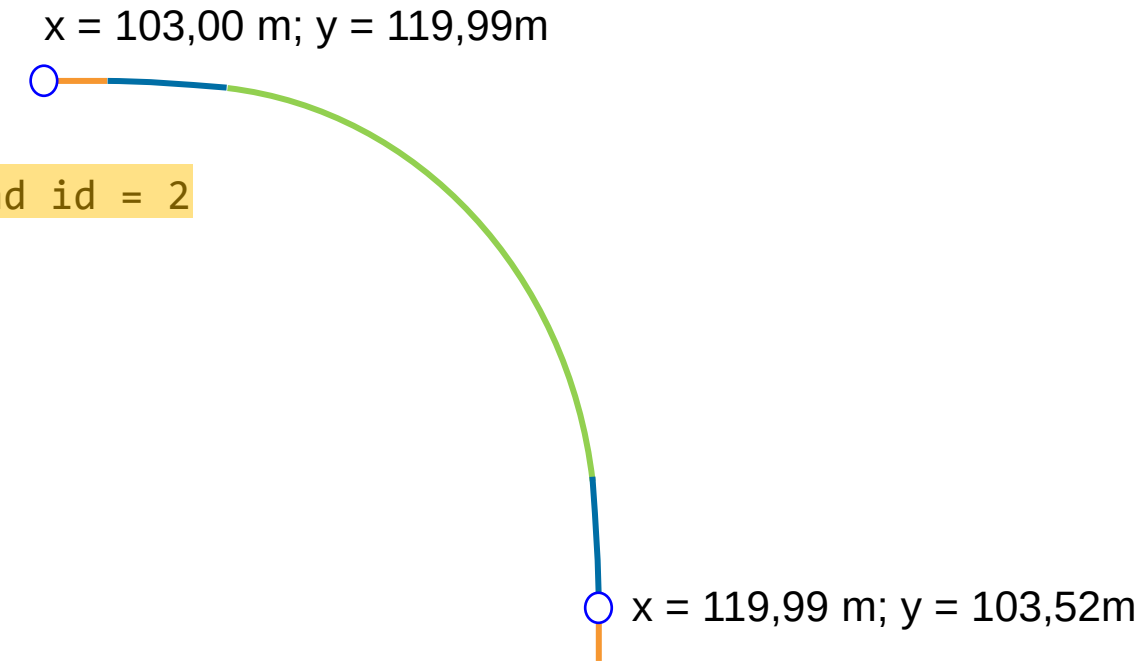
```
<road rule="RHT" length="2.8435719942688948e+01" id="2" junction="1">
    <link>
        <predecessor elementType="road" elementId="6"
        <successor elementType="road" elementId="1"
    </link>
```



ASAM

ASAM OpenDRIVE: Junctions

Shape of the connecting roads

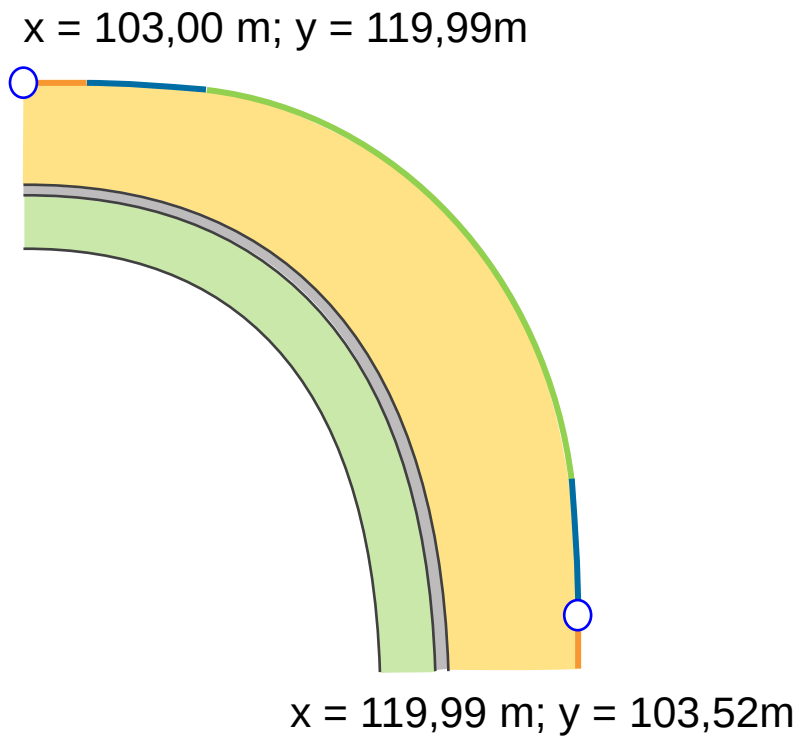



```
<road rule="RHT" length="2.8435719942688948e+01" id="2" junction="1">
    <link>
        <predecessor elementType="road" elementId="6" contactPoint="start" />
        <successor elementType="road" elementId="1" contactPoint="start" />
    </link>
    <type s="0.0000000000000000e+00" type="town" country="DE"/>
    <planView>
        <geometry s="0.0000000000000000e+00" x="1.0300000000003085e+02" y="1.1999999999995786e+02" hdg="3.8356854067442034e-12" length="5.1868687057341845e-01">
            <line/>
        </geometry>
        <geometry s="5.1868687057341845e-01" x="1.0351868687060427e+02" y="1.1999999999995985e+02" hdg="-6.1026739217595605e-12" length="8.9414893617021267e+00">
            <spiral curvStart="-0.0000000000000000e+00" curvEnd="-8.5106382978723402e-02"/>
        </geometry>
        <geometry s="9.4601762322755452e+00" x="1.1233159338882540e+02" y="1.1887762726397237e+02" hdg="-3.8048890901346244e-01" length="9.5153674781379021e+00">
            <arc curvature="-8.5106382978723402e-02"/>
        </geometry>
        <geometry s="1.8975543710413447e+01" x="1.1887762085662244e+02" y="1.1233159979616045e+02" hdg="-1.1903074177911561e+00" length="8.9414893617021267e+00">
            <spiral curvStart="-8.5106382978723402e-02" curvEnd="-0.0000000000000000e+00"/>
        </geometry>
        <geometry s="2.7917033072115572e+01" x="1.1999999359271642e+02" y="1.0351869327797370e+02" hdg="-1.5707963267960539e+00" length="5.1868687057337581e-01">
            <line/>
        </geometry>
    </planView>
```


ASAM

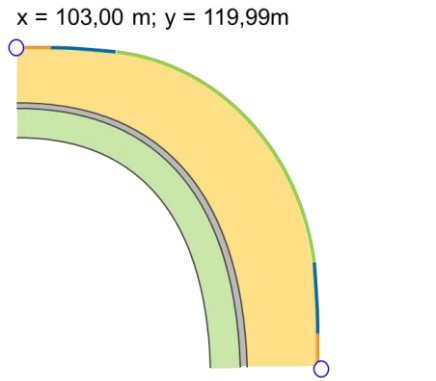
ASAM OpenDRIVE: Junctions

```
<right>
    <lane id="-1" type="driving" level="false">
        <link>
            <predecessor id="1"/>
            <successor id="-1"/>
        </link>
        <width sOffset="0.0000000000000000e+00" a="3.7500000000000000e+00" b="0.00
    </lane>
    <lane id="-2" type="border" level="false">
        <link>
            <predecessor id="2"/>
            <successor id="-2"/>
        </link>
        <width sOffset="0.0000000000000000e+00" a="3.4999999999999998e-01" b="0.00
    </lane>
    <lane id="-3" type="sidewalk" level="false">
        <link>
            <predecessor id="3"/>
            <successor id="-3"/>
        </link>
```



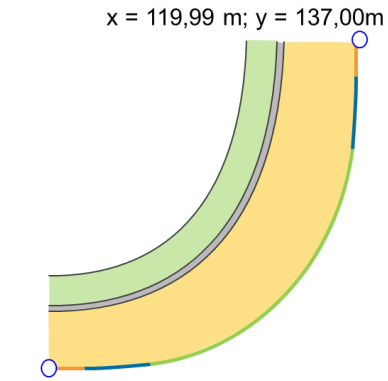
ASAM OpenDRIVE: Junction

road id = 2



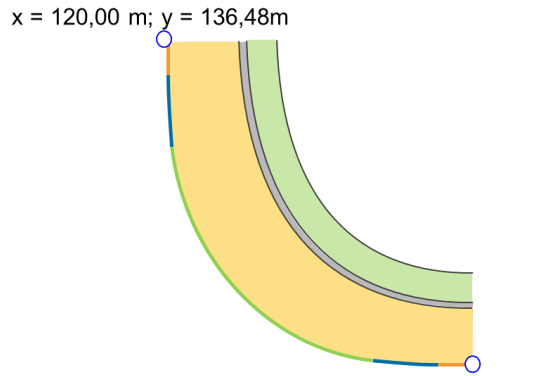
predecessor road: 6
successor road: 1

road id = 3



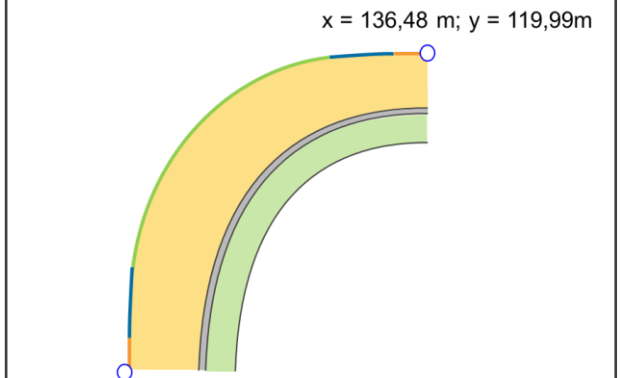
predecessor road: 0
successor road: 6

road id = 9



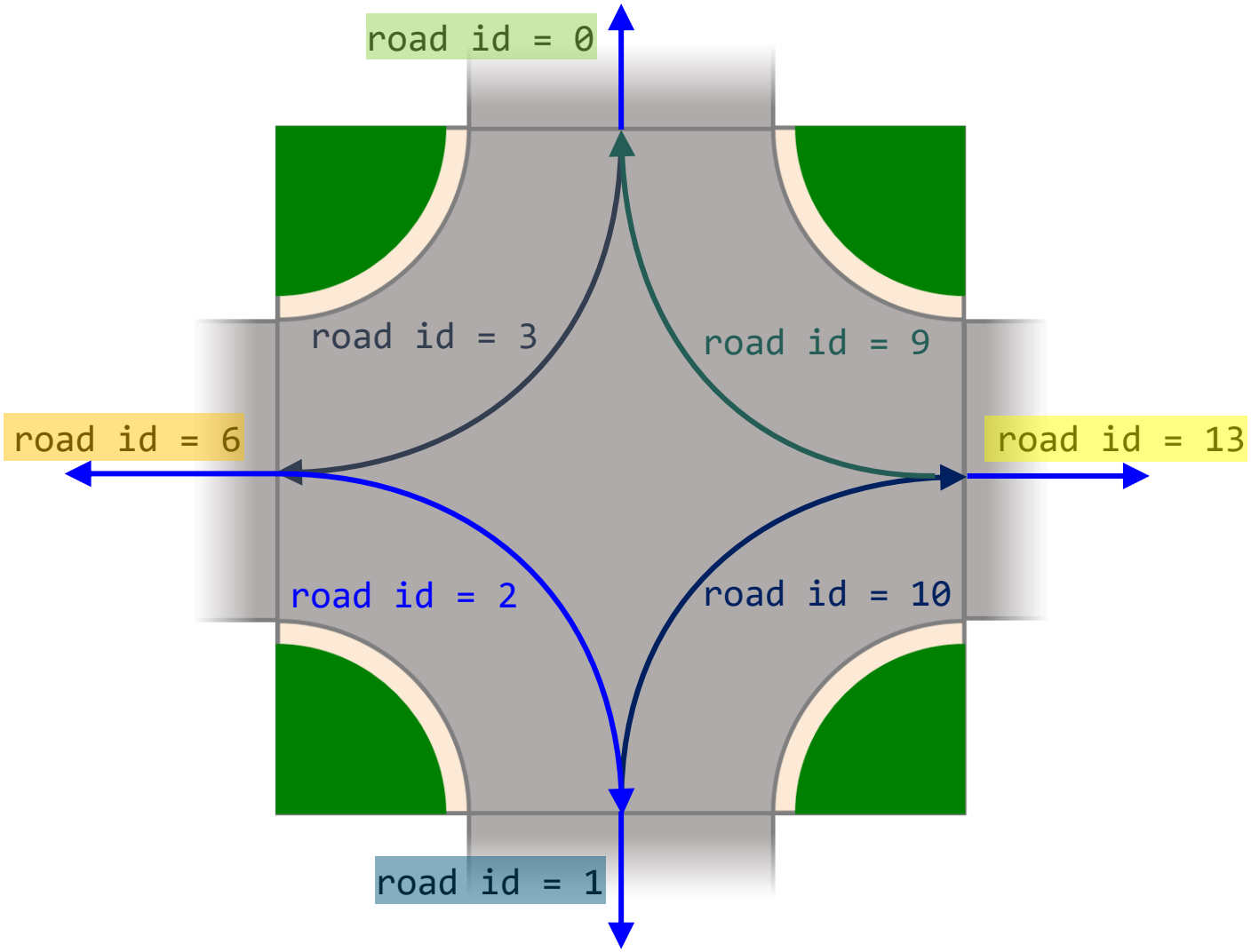
predecessor road: 13
successor road: 0

road id = 10

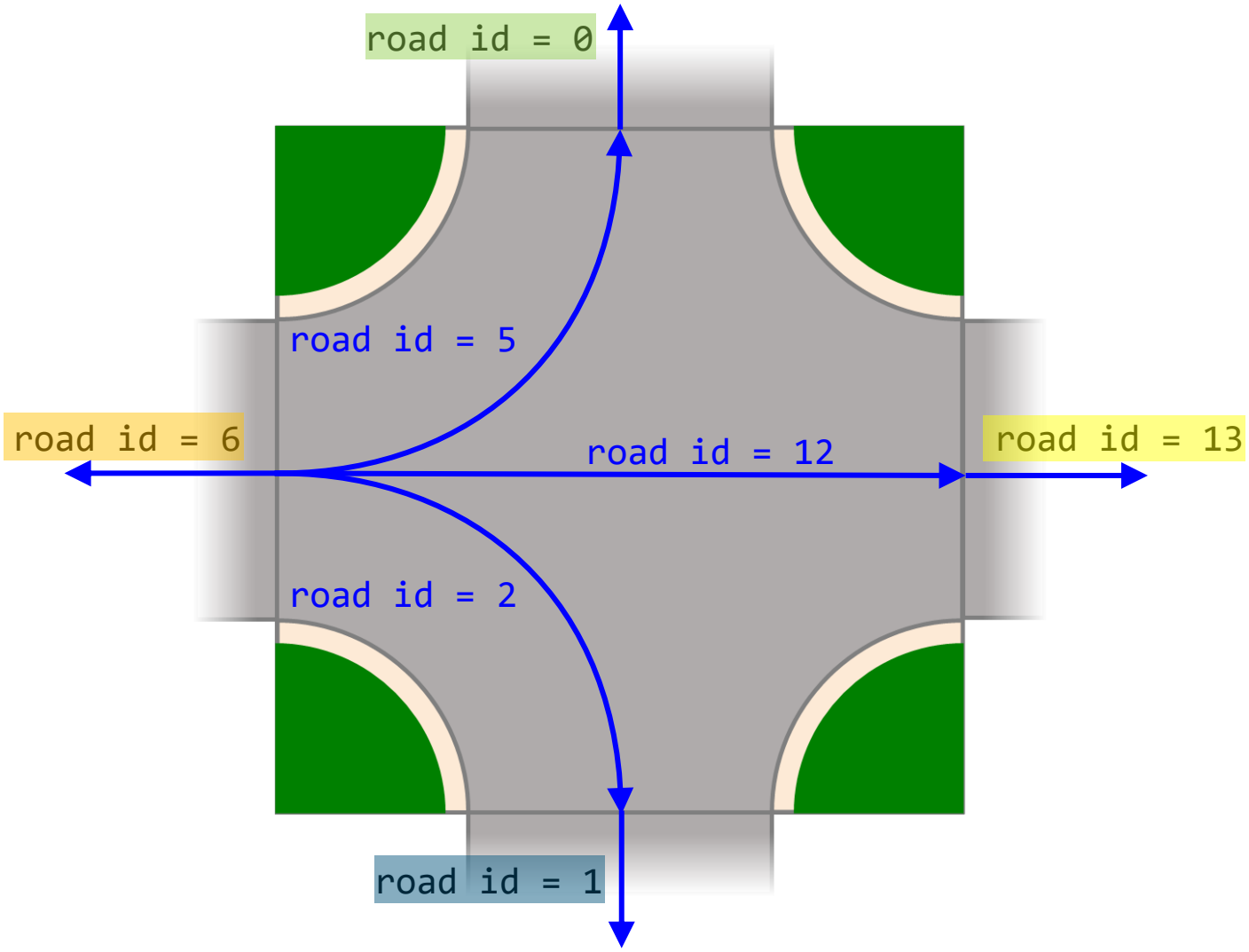


predecessor road: 1
successor road: 13

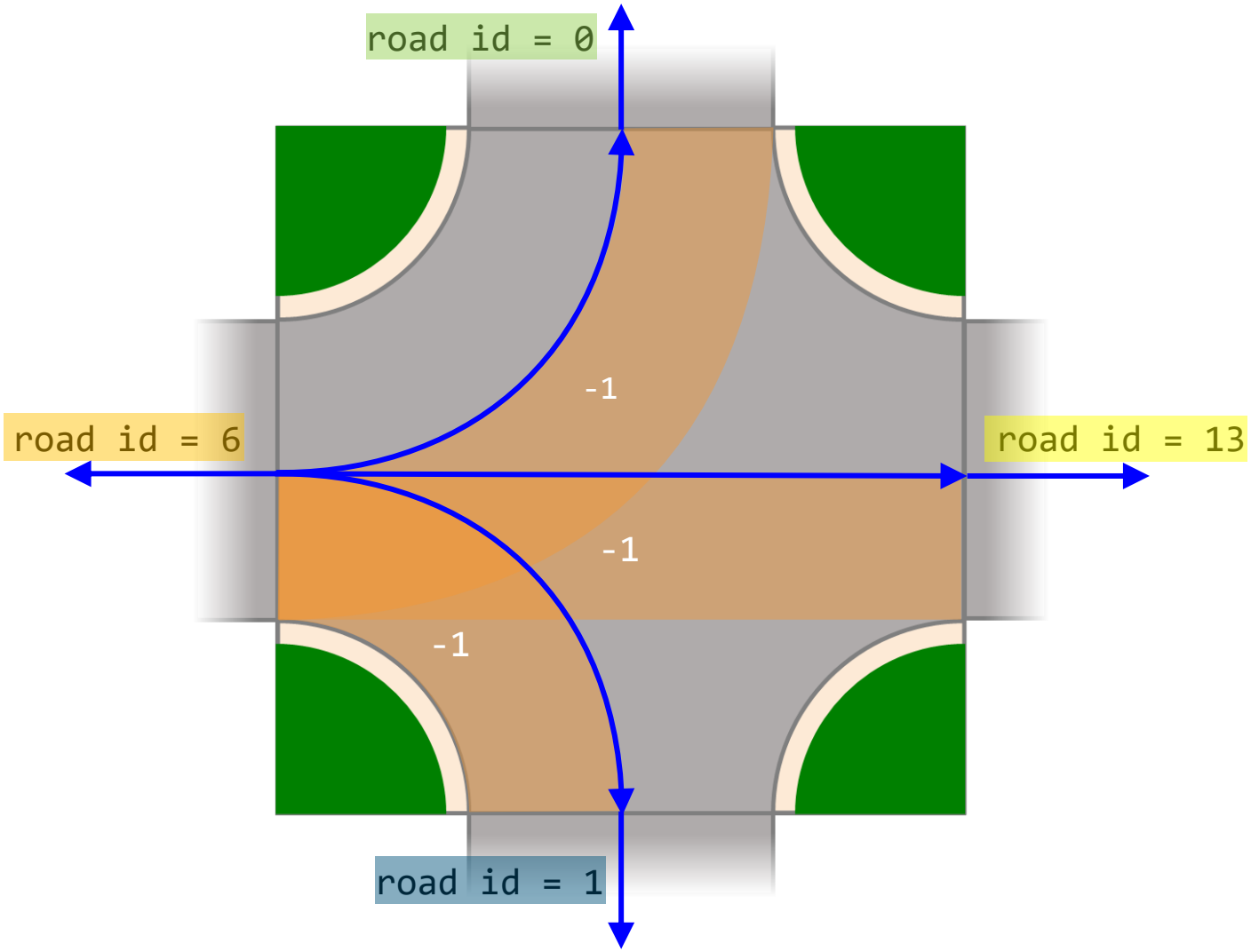
ASAM OpenDRIVE: Junctions



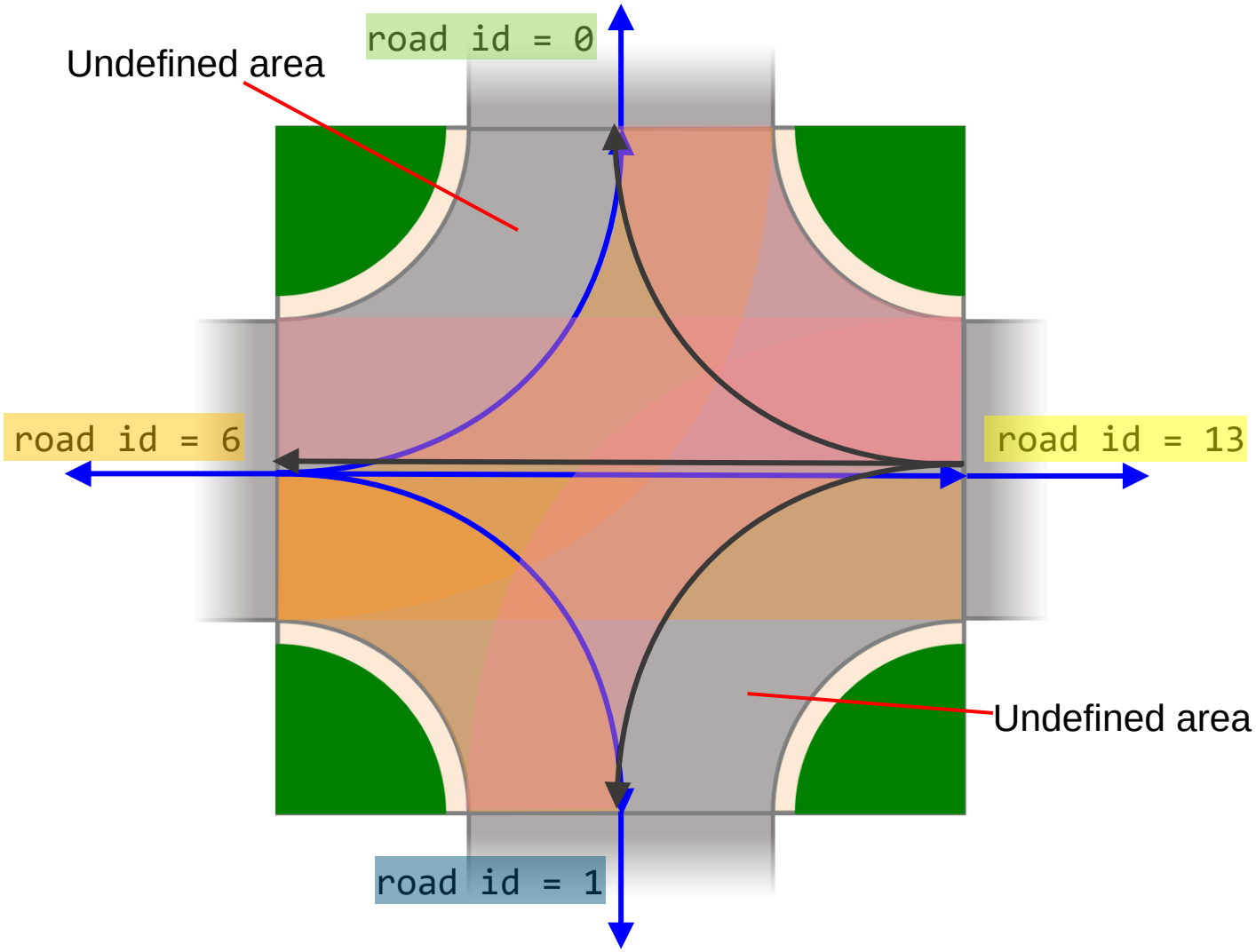
ASAM OpenDRIVE: Junctions



ASAM OpenDRIVE: Junctions



ASAM OpenDRIVE: Junctions



ASAM OpenDRIVE: Junctions