CONFIGURATION AND GENERATION OF ROAD SEGMENTS AND JUNCTIONS FOR VERIFICATION OF AUTONOMOUS SYSTEMS

Kick-Off Workshop ASAM OpenDRIVE 2018-10

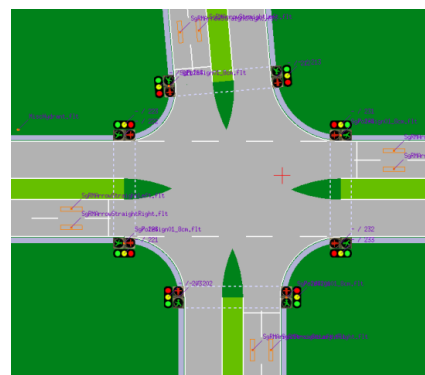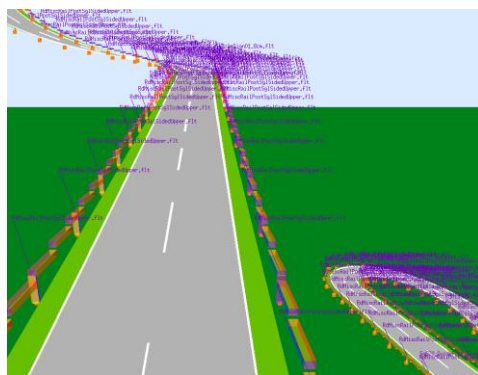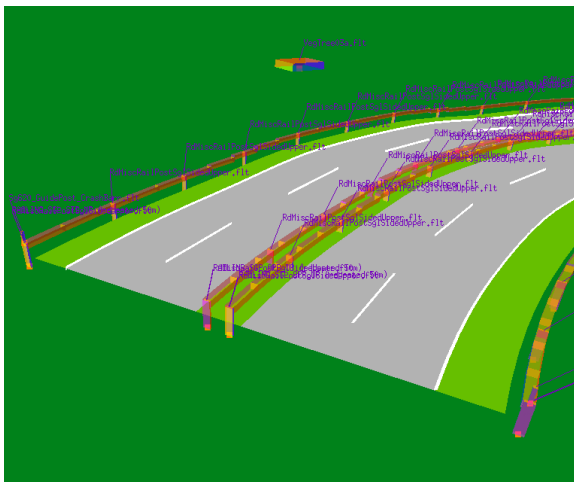Martin Herrmann, Martin Butz – Bosch Corporate Research

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Verification of Autonomous Systems

Road Configuration (SCODE)

Dimension	NOT	Alte...e 1	Alte...e 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	A
roadtype	☐	motorway	rural	town	lowSpeed	pedestrian	bicycle	u
roadtype-special	☐	none	town-solid	motorway-2x2L	motorway-2x2L-StopL	motorway-2x4L-StopL	rural-bike	
heading	☐	0	30	45	90	180	270	
shape	☐	0	90	-90	s-curve	s100s100a30	-45	-
elevation	☐	0	-0.2	0.2	1plateau	3hills5	10hills5	5
length	☐	50	100	200	400	500	1000	2
tunnel	☐	0	1	2				
bridge	☐	0	1	2				
vegetation	☐	0	1					
animal	☐	0	1	2				
building	☐	0	1					
guide-posts	☐	0	1					
guardrail	☐	0	1					

▶ Mission: Develop methods and tools for the model-based verification of autonomous systems

▶ Goal: Automated generation of relevant test cases for SIL simulation from structured, formalized scenarios

    ▶ Configure and generate the static elements of a scenario -> OpenDrive

    ▶ Add dynamic agents -> OpenScenario

    ▶ Simulate and apply optimization-driven approach

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Gapless Roads without redundant information
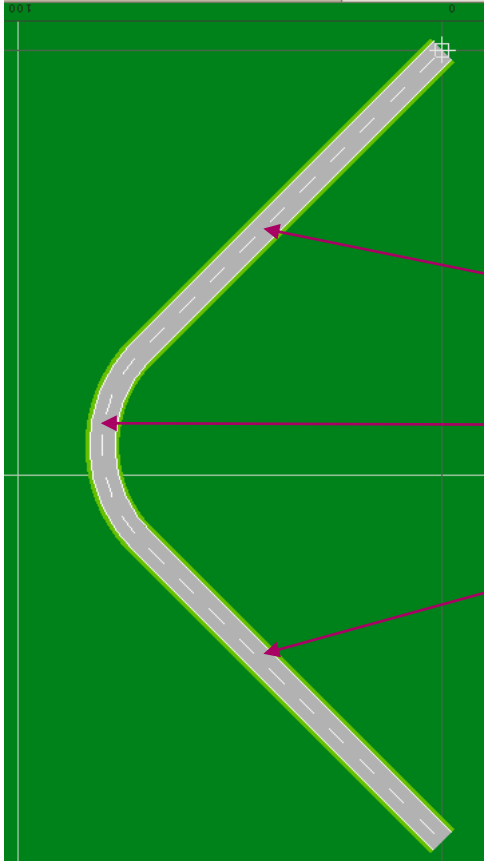
▶ Goal: Enable easy combination of road geometries

▶ Example: combine two straight road segments with a curve
current state:

```xml
<road name="Highway2Hell" length="250" id="1" junction="-1">
    <type s="0" type="rural"/>
    <planView>
        <geometry s="0" x="0" y="0" hdg="0.785398163397448" length="100">
            <line/>
        </geometry>
        <geometry s="100" x="70.711" y="70.711" hdg="0.7853981" length="50">
            <arc curvature="0.0314159"/>
        </geometry>
        <geometry s="150" x="70.711" y="115.727" hdg="2.356194" length="100">
            <line/>
        </geometry>
```
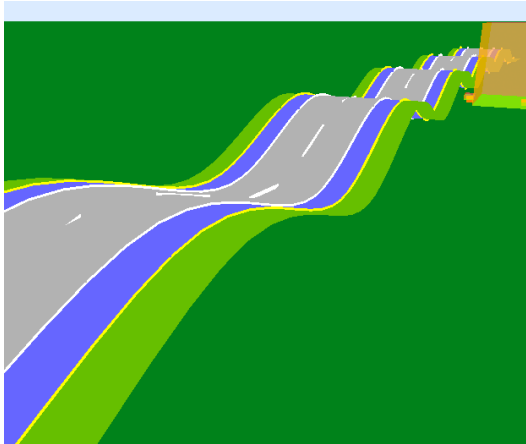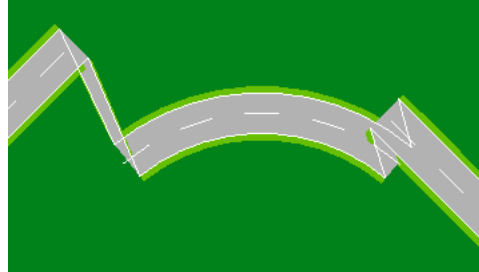
Redundant information

▶ What it should be:

```xml
<road name="Highway2Hell" id="1" junction="-1">
    <type s="0" type="rural"/>
    <planView>
        <geometry s="0" x="0" y="0" hdg="0.785398163397448" length="100">
            <line/>
        </geometry>
        <geometry length="50">
            <arc curvature="0.0314159"/>
        </geometry>
        <geometry length="100">
            <line/>
        </geometry>
```

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Gapless Roads without redundant information

▶ What happens if x/y-coordinates are wrong:

▶ Same for e.g. elevation

```
<elevation s="100" a="0"  b="0" c="0.0015" d="-1e-005"/>
<elevation s="200" a="5"  b="0" c="0"      d="0"/>
<elevation s="300" a="5"  b="0" c="-0.0015" d="1e-005"/>
<elevation s="400" a="0"  b="0" c="0"      d="0"/>
```

Redundant
information

▶ Put all trigonometric calculations into viewer/simulator

▶ Make attributes optional

   ▶ if missing assume gapless roads

   ▶ if available -> use them -> backwards compatible

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Road Objects

▶ To generate realistic environments we need additional elements

  ▶ Guide posts, guard rails, vegetation, buildings, bridges, tunnels, pedestrians, animals, hydrants, recycle bins, bus stops, street lights, illuminated advertising, …

▶ Library of 3D road objects

  ▶ Open, expandable

  ▶ Usable in all viewers, editors, simulators

  ▶ Support animation (e.g. walking pedestrians, rotating wind turbine)

    – Controllable via signals from OpenScenario (e.g. switch on street light)

  ▶ Format: e.g. glTF from Khronos Group https://www.khronos.org/gltf/

  ▶ Scalable objects

  ▶ Add hints for correct position, e.g. zOffset values for posts

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Surface and horizon

▶ Add a simple way to add a surface to both sides of a road

- ▶ Follow elevation of road
- ▶ Should also work for not even terrain like pass roads
- ▶ Smooth transition to other roads and junctions
  - – How to handle z-positioning of road objects like vegetation?
- ▶ Should consider tunnels and bridges

▶ Enable to add a horizon (end-of-terrain)

- ▶ City, mountains, forest, wall, fence, …

▶ Goal: Enable to specify a complete static scenario

- ▶ Not only a floating road in free space

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Traffic Signs

▶ Support all traffic signs and lights

  ▶ All major countries

  ▶ At least all German signs and lights according to
    https://de.wikipedia.org/wiki/Bildtafel_der_Verkehrszeichen_in_der_Bundesrepublik_Deutschland_seit_2017

  ▶ Provide a catalog with pictures and options (value = speed limit)

  ▶ Use type, subtype and value

  ▶ Use country attribute (and not country=„OpenDRIVE")

  ▶ Add option to easily add a post (to avoid hovering traffic signs)

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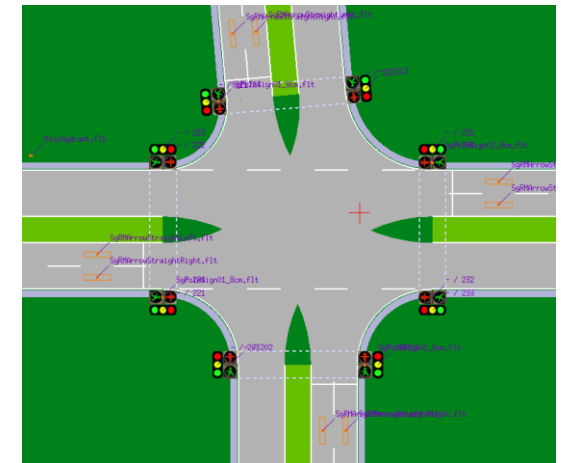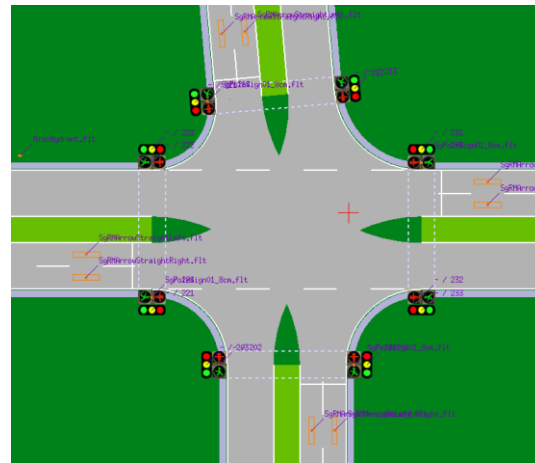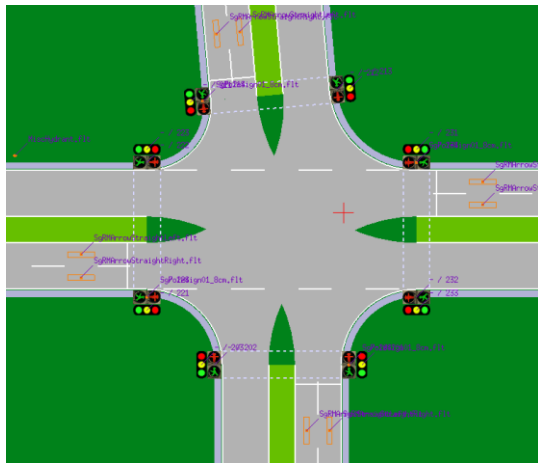# OpenDrive - Kick-Off Workshop ASAM
Junctions
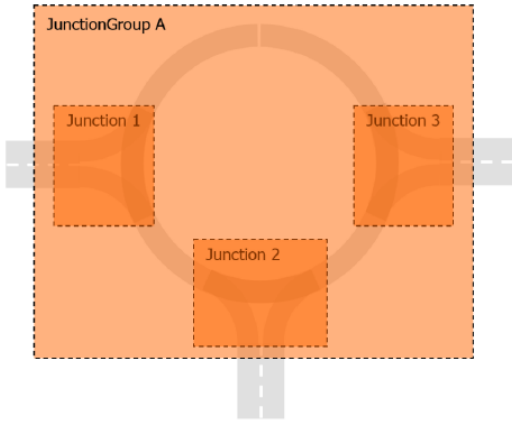
▶ Rough idea:

    ▶ Simplify roundabouts

        – Special handling for roundabouts instead of combination of several junctions

        – Should support at least standard roundabouts
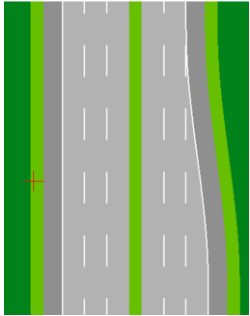
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Reference Implementation

▶ To get the comparable results in all viewers, editors and simulators we need a reference implementation

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Documentation

▶ Improve OpenDrive documentation

  ▶ Add complete XML parts (copy-and-paste)
  ```
  <signal s="50" t="-3.2" id="200" name="VorfahrtAchten" dynamic="no" orientation="+"
  zOffset="4" type="205" country="OpenDRIVE" subtype="-1" value="-1"/>
  ```

  ▶ Add all supported signals and objects with pictures

  ▶ Add formulas for smooth transitions (lane merge, elevation)
  $$c = 3*(b2-b1)/d^2 \quad d = 2*(b1-b2)/d^3$$

  ▶ Add simple but complete OpenDrive examples files

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Requirements Summary
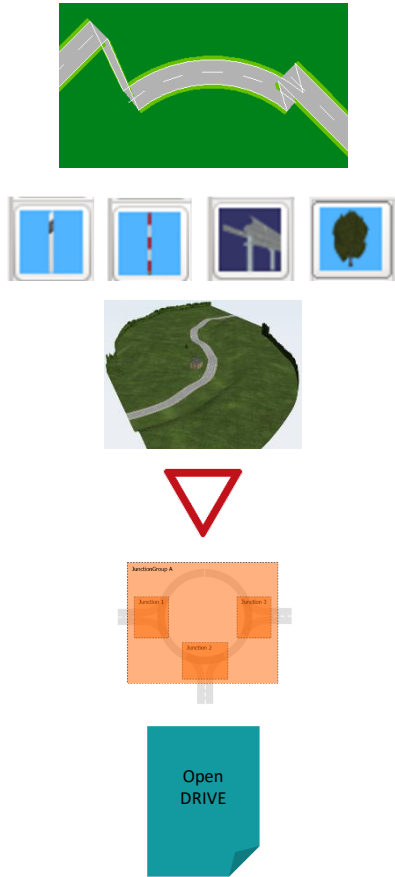
▶ Remove redundant information

▶ Library of 3D road objects

▶ Add surface and horizon

▶ Support all traffic signs

▶ New roundabouts element

▶ Reference implementation

▶ Improve documentation

▶ Other

    ▶ Weather and sun position -> better handled in OpenScenario or other format

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