Generation of Highway Sections for Automated Test Case Creation

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PEGASUS

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PEGASUS: Key Figures

42 months term	January 1, 2016 – June 30, 2019
17 Partners	▪ OEM: Audi, BMW, Daimler, Opel, Volkswagen ▪ Tier 1: Automotive Distance Control, Bosch, Continental Teves ▪ Test Lab: TÜV SÜD ▪ SMB: fka, iMAR, IPG, QTronic, TraceTronic, VIRES ▪ Scientific institutes: DLR, TU Darmstadt
12 Subcontracts	▪ i.a. IFR, ika, OFFIS
Project Volume	▪ approx. 34,5 Mio. EUR ▪ Subsidies: 16,3 Mio. EUR
Personnel Deployment	▪ approx. 1.791 man-month or 149 man-years

Current State of Development of HAD

Prototypes

- Multitude of prototypes built by OEM with HAD-functionality
- Evidence, that HAD is technologically possible
- Partially tested in real traffic situations
- Test drives involve backup safety driver at all times

Lab / Proving Ground

- Individual analyses to optimize prototypes
- Current test methods/ proving grounds do not provide enough test coverage for all HAD features currently in focus
- There is no procedure for adequate testing/validation (particularly performance) of HAD-systems

Products

- No release or introduction of variety of HAD features without sufficient assurance

current status

Resulting Starting Position – Automated Driving

Together with electric driving, automated driving is tomorrow's subject matter.

Basic functionality is technologically given

Has been demonstrated in various projects

High standards regarding quality and performance of the automated vehicle

➔ Measures that product needs to meet

Existing measures for testing and release are insufficient, too cost-intensive and too complex

➔ Consequently, the introduction of highly automated driving features today can only be achieved with great expenditure.

Central Issues of the Project

What level of performance is expected of an automated vehicle?
How can we verify that it achieves the desired performance consistently?

Scenario Analysis & Quality Measures

- What human capacity does the application require?
- What about technical capacity?
- Is it sufficiently accepted?
- Which criteria and measures can be deducted from it?

Implementation Process

- Which tools, methods and processes are necessary?

Testing

- How can complete-ness of relevant test runs be ensured?
- What do the criteria and measures for these test runs look like?
- What can be tested in labs or in simulation? What must be tested on proving grounds, what must be tested on the road?

Reflection of Results & Embedding

- Is the concept sustainable?
- How does the process of embedding work?

Background

- Simulation as one pillar of testing strategy
  - cost efficiency, high test coverage
- Selective variation of test parameters needed
  - e.g. street `width`, `length`, `curvature`
- Detailed specification of test cases needed
  - Behavior of traffic participants and dynamic content (OpenSCENARIO)
  - Topological and topographical description of road networks (OpenDRIVE)

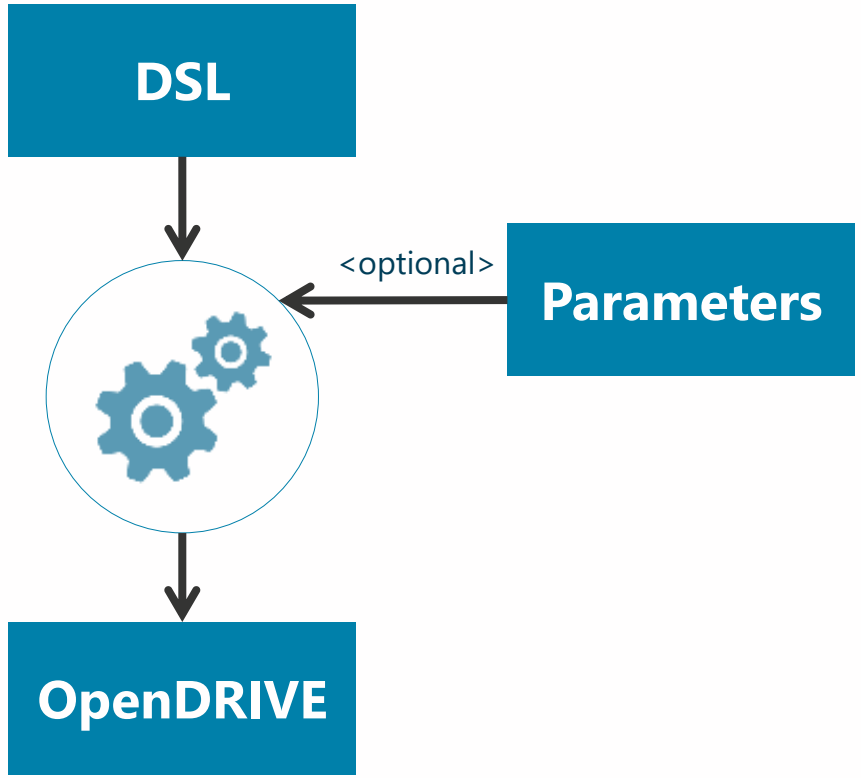
- OpenDRIVE is the de-facto standard for simulation as supported by large quantity of tools
  - Modelling is complex and time consuming …
  - XML is complex with several dependencies between elements …

Source: http://opendrive.org

Generation of OpenDRIVE

- How can OpenDRIVE be effectively generated with variations/parametrizations?

- Can a DSL (domain specific language) be used to efficiently model (various variants of) highways to describe test cases?
  - Common approach to reduce complexity and increase efficiency for testing purposes
  - DSL document can contain variables, which are replaced with concrete values (e.g. street `width`, `length`, `curvature`)
  - Optional variable substitution is performed as preprocessing before further transformation of DSL



SimplifiedRoad

- XML-based, abstract track description for OpenDRIVE
  - Same naming of XML elements
- Current focus on highways
  - Enhancements/extensions for extra-urban regions planned for 2019
- Simplifications/Limitations
  - Supports cross sections from RAA (guidelines for designing highways)
  - Uses reasonable default values where possible
  - Several elements are specified as flags without (detailed) configuration (e.g. infrastructure)
- Features
  - Manual track creation possible → allows rapid design
  - Local changes without impact on other road sections
    - Important for variants
  - New: support for varying/changing lane width between cross sections

```
<section length="1000">
  <road crossSection="RQ36" mirror="true"/>
</section>

<section length="1000">
  <road crossSection="RQ36" mirror="true"/>
  <course>
    <arc radius="250"/>
  </course>
</section>
```

Example: Line, curve

Results

- Second release of transformation engine available
  - Realized in Java
  - Command line application and/or web service for easy integration
  - Integration into PEGASUS toolchains currently in progress
- SimplifiedRoad results in much smaller documents
  - About ~10% of code needed in experiments
  - Strongly depending of used features and modelling
  - Functional test cases from development used
  - Creation with XML editor quite easy

File	OpenDRIVE		SimplifiedRoad	
	Lines	Chars	Lines	Chars
1	1,456	85,322	7.55%	5.12%
2	80	3,039	15.00%	14.58%
3	321	12,910	21.18%	10.60%
4	125	4,976	9.60%	9.16%
5	187	7,183	10.16%	8.27%
6	319	13,588	6.90%	5.53%
7	187	7,124	8.56%	7.62%
8	201	8,377	9.95%	8.63%

```
<road length="1000.0" id="0">
  <link>
    <successor elementType="road"
      elementId="1" contactPoint="start"/>
  </link>
  <type s="0.0" type="motorway"/>
  <planView>
    <geometry x="1000.0" 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"/>
```

Partial OpenDRIVE for **ONE** road section (curve)
6 lines in SimplifiedRoad

Visualization of file 1

Summary & Outlook

- Summary
  - OpenDRIVE is powerful, but was not made to be edited manually at XML-level
  - Using a DSL to efficiently model highway sections is possible
    - For efficiency simplifications are made
  - SimplifiedRoad does not replace visual scenario editors or OpenDRIVE, but complements for certain use cases (e.g. test scenarios, rapid prototyping)
- Outlook
  - Planned & possible features
    - Highway entries and exits
    - Automated positioning of signals/signs
    - Extra-urban roads
    - Construction sites
    - …
  - Further evaluation in PEGASUS testing toolchain

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