Generation of Highway Sections for Automated Test Case Creation

Michael Scholz, Ulf Noyer, Andreas Richter
## PEGASUS: Key Figures

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 months term</td>
<td>January 1, 2016 – June 30, 2019</td>
</tr>
<tr>
<td>17 Partners</td>
<td>- OEM: Audi, BMW, Daimler, Opel, Volkswagen</td>
</tr>
<tr>
<td></td>
<td>- Tier 1: Automotive Distance Control, Bosch, Continental Teves</td>
</tr>
<tr>
<td></td>
<td>- Test Lab: TÜV SÜD</td>
</tr>
<tr>
<td></td>
<td>- SMB: fka, iMAR, IPG, QTronic, TraceTronic, VIRES</td>
</tr>
<tr>
<td></td>
<td>- Scientific institutes: DLR, TU Darmstadt</td>
</tr>
<tr>
<td>12 Subcontracts</td>
<td>- i.a. IFR, ika, OFFIS</td>
</tr>
<tr>
<td>Project Volume</td>
<td>- approx. 34,5 Mio. EUR</td>
</tr>
<tr>
<td></td>
<td>- Subsidies: 16,3 Mio. EUR</td>
</tr>
<tr>
<td>Personnel Deployment</td>
<td>- approx. 1.791 man-month or 149 man-years</td>
</tr>
</tbody>
</table>
### Current State of Development of HAD

<table>
<thead>
<tr>
<th>Prototypes</th>
<th>Lab / Proving Ground</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Multitude of prototypes built by OEM with HAD-functionality</td>
<td>▪ Individual analyses to optimize prototypes</td>
<td>▪ No release or introduction of variety of HAD features without sufficient assurance</td>
</tr>
<tr>
<td>▪ Evidence, that HAD is technologically possible</td>
<td>▪ Current test methods/ proving grounds do not provide enough test coverage for all HAD features currently in focus</td>
<td></td>
</tr>
<tr>
<td>▪ Partially tested in real traffic situations</td>
<td>▪ There is no procedure for adequate testing/validation (particularly performance) of HAD-systems</td>
<td></td>
</tr>
<tr>
<td>▪ Test drives involve backup safety driver at all times</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 completeness 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?
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
Motivation

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
Road Specification

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

Example: Line, curve

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

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

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