Simulating Digital Rail
From PlanPro railway plannings to SUMO simulations

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Research:

Digital Rail
- mFund Researchprojects with DB Systel, DB Netz (and others): Rail2X, DiAK, RailChain, FlexiDug
- Distributed IoT-Lab for Testautomation

Telemed5000 (Charité)

Teaching:
- Operating Systems
- Parallel and Distributed Systems
- Embedded Systems
- Digital Rail Summer School (2019-22, hpi.de/drss)
The railway domain is getting more and more digital, with new digital devices, processes and open standards.

But introducing new devices is a complex process to guarantee interoperability and conformity with existing systems.

This so far contains several manual steps, this does not scale.

Our Idea: Use digital plannings of railway networks to operate/simulate the railway network, containing the new device and several existing ones.

Therefore we need:

**Motivation**

- Digital Testcase-Catalog
- Realistic Test-Environments
- Test-Execution System
- Evaluation
- Automatable Configuration

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Chart 3
PlanPro

- A data format, that contains all details about a planned railway network
- Core-part of a full digital planning process – away from paper-based towards digital processes
- XML-based: (but in German)

```xml
<Container>
  <Fstr_Fahrweg/></Fstr_Fahrweg>
  <GEO_Knoten/></GEO_Knoten>
  <Signal/></Signal>
  <TOP_Kante/></TOP_Kante>
  <TOP_Knoten/></TOP_Knoten>
</Container>
```

- Verbose format – already small examples creates massiv file sizes

(Picture shows the PlanPro Werkzeugkoffer (toolbox), a software to display and analyse PlanPro files)
## PlanPro Network Creation

<table>
<thead>
<tr>
<th>ProSig 7 / ProVi</th>
<th>PlanPro Generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Typical planning tools of DB can already export to PlanPro files</td>
<td>• Create small PlanPro examples</td>
</tr>
<tr>
<td>• Contains many details about infrastructure, geography and more</td>
<td>• Only contains the most relevant aspects of a planning</td>
</tr>
<tr>
<td>• Extensive to create, so only a few railway networks are exported to PlanPro through ProSig 7 / ProVi</td>
<td>• Strong abstraction with large focus on test automation</td>
</tr>
<tr>
<td>• Closed-source, expensive</td>
<td>• Allows us to create many different scenarios</td>
</tr>
</tbody>
</table>

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Chart 5

Available on GitLab: [https://gitlab.hpi.de/arne.boockmeyer/planpro-generator](https://gitlab.hpi.de/arne.boockmeyer/planpro-generator)
To simulate the railway networks in SUMO, a transformation between the two file formats is necessary.

SUMO-Plain-XML is used as a step in between:

Available auf GitLab: [https://gitlab.hpi.de/arne.boockmeyer/planpro-sumo-converter](https://gitlab.hpi.de/arne.boockmeyer/planpro-sumo-converter)
PlanPro to SUMO Dictionary

- Every TOP_Kante can cover multiple GEO_Kanten
- A GEO_Kante is a function defining the pathway of the rails (Straight, Arc, Clothoid, …) – right now all interpreted as straights
Challenges during Development

In PlanPro, Signals are annotations to TOP_Kanten

SUMO uses nodes as signals

Separating TOP_Kanten causes a lot of confusion during the processing of routes

The position of signals is defined by the distance from the start of the TOP_Kante

SUMO needs exact coordinates

Since every TOP_Kante can cover multiple GEO_Kanten, the related GEO_Kante needs to be determined

The position of the signal than was estimated by the remaining distance
Generation of Routes

- Every route starts at a signal, ends at a signal and covers (multiple) edges
- To generate the routes, a Python-package was developed:
  - The algorithm is a DFS on the topology with a modified neighbor-function
  - Available on GitLab: https://gitlab.hpi.de/arne.boockmeyer/planpro-running-track-generator

Topology as:
- PlanPro (.ppxml)
- JSON*

Routes as:
- JSON
- PlanPro (.ppxml)*

(*: planned)
The Test Controller is a console application that allows the test manager to:

- Print details about the setup of the railway network (incl. routes)
- Show conflicts between routes
- Create trains on routes
- Run all routes (and their combinations)

It contains a basic interlocking

- Manage state of network
- Orchestrating the signals
- Detect conflicts

... and run the SUMO-Simulation!
Demo
Marvis is a hybrid IoT-Testbed, containing:
- Co-Simulation of SUMO and ns-3
- Simulated Nodes and Hardware-in-the-loop
- Fault injection capabilities

Research-Paper:
- Beilharz et. al., “Towards a Staging Environment for the Internet of Things.”, PerCom Workshops, 2021

Available on GitHub: [https://github.com/diselab/marvis](https://github.com/diselab/marvis)
The EULYNX-Live-Lab orchestrates connected tests with several devices at different locations.

- Allows to exchange devices and protocols with Kubernetes.
- Contains a generic interlocking as central component.

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Chart 13
Next Steps

Take more details from the PlanPro-file to enrich the SUMO-network (e.g. more types of signals, train detection systems, ...)

- Get geography more precise (solve functions to get more points in between)
- Connect to execution environments to have full test environment (to Marvis or the EULYNX-Live lab)

(if anybody has further ideas, knowledge on some of these points, or anything else, please contact us under arne.boockmeyer@hpi.de)
The PlanPro-Format should be the standard for future full-digital plannings.

It contains many details about infrastructure, geography, ...

The transformation process transforms it to a SUMO network:

The test controller allows the test manager to operate trains in the SUMO network to achieve test automation.
Image Sources


Other images:
Manufactures-Logos from their organizations and company’s
Icons by Microsoft Office
Graphics from our research group
Screenshots from PlanPro tools and plannings
Screenshots of SUMO (https://sumo.dlr.de)