Trier University
of Applied Sciences

HOCHSCHULE TRIER

FORSCHUNGSVERBUND
VERKEHRSTECHNIK &
VERKEHRSSICHERHEIT

Compilation of driving simulation languages via retargetable and semantics-based translation

Prof. Dr.-Ing. Jörn Schneider

Kontakt: J.Schneider@hochschule-trier.de

Interdisciplinary Research

FORSCHUNGSVERBUND
VERKEHRSTECHNIK &
VERKEHRSSICHERHEIT

Engineering & Computer Science
@
Trier University of Applied Sciences

+

Cognitive Psychology
@
University of Trier

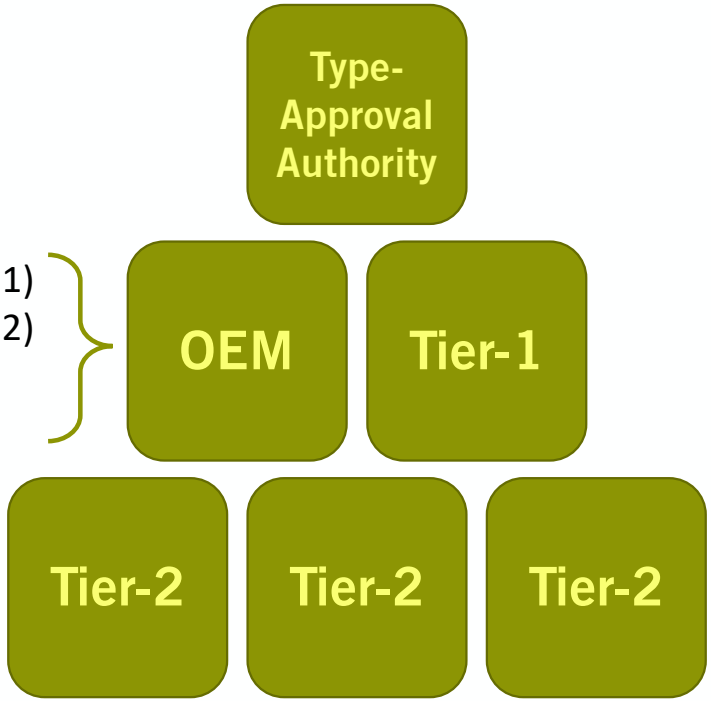
FVV – Research Cluster for Traffic Technology and Traffic Safety

Our Driving Simulator FaSiMo

Two Simulation Targets: Human Driver *and* Automated Driving System

New Tower of Babel: Driving Simulator Languages

Internally:
ASAM OpenDrive V 1.7 (Unit 1)
ASAM OpenDrive V 2.0 (Unit 2)
SILAB (Unit 3)
…



Translation Required!

Outline

- **Objectives**
- Retargetable Translator
- Challenge: Semantics
- Solution Idea
- Translation Semantics
- Conclusion

Reliable Translation

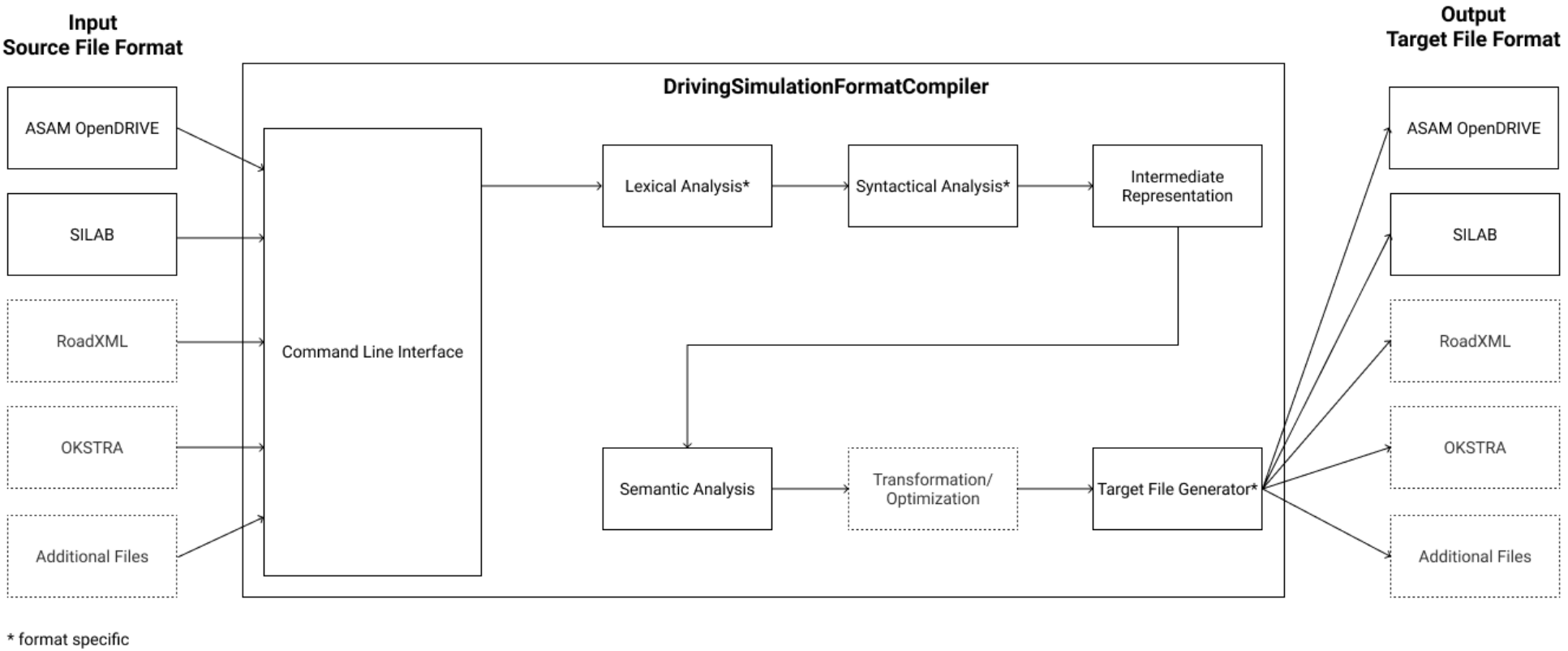
- Development Processes according to Safety standards, such as SOTIF, rely on simulation
- Type Approval of Automated Driving Functions will rely on driving simulation

- Consequence:
  Correctness of translation is fundamental for safety and reliability of our future mobility

Formal Semantics is needed!

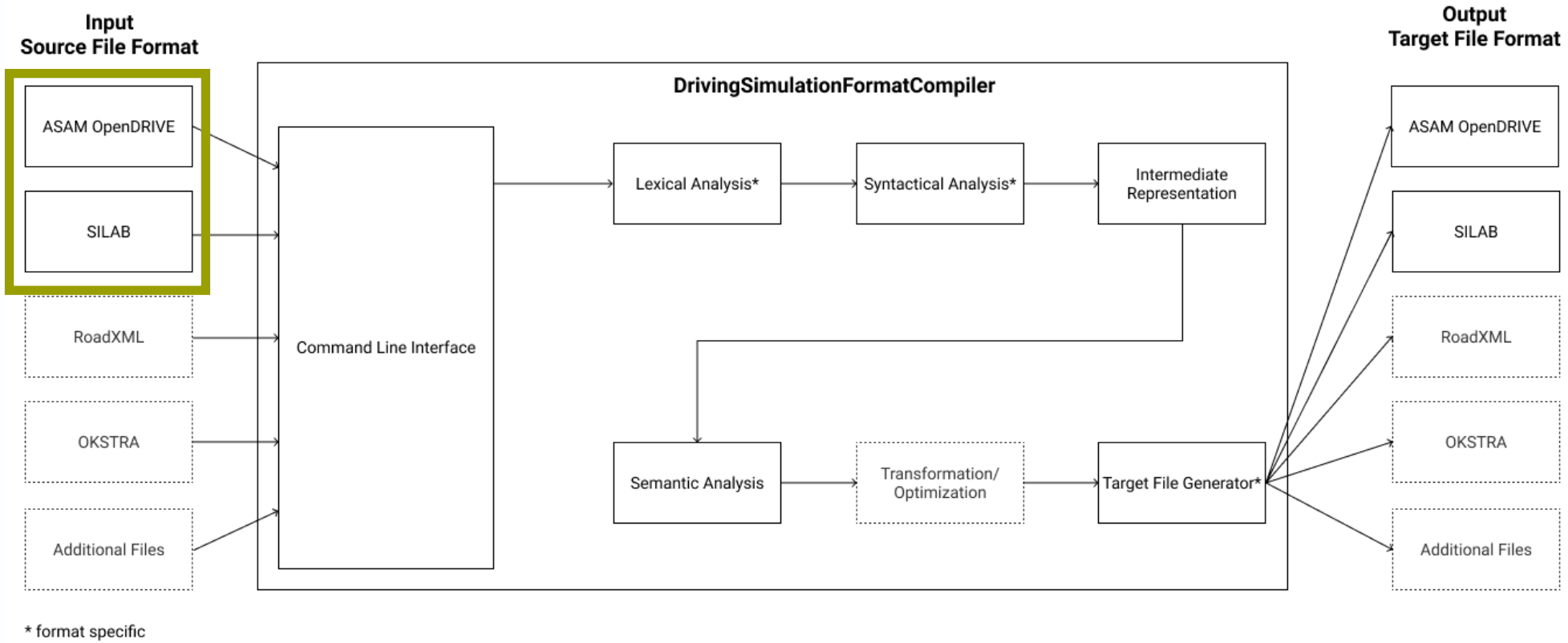
- Semantics attaches „meaning“ to syntax
- Syntax of languages might differ, but the „meaning“ must be well defined!
- Formal Semantics fundamental to
  - Specify „meaning“ of language constructs
  - Generate tools (Translators, Analyzers, …)
  - Test or verify correctness
- How to validate or verify whether a translation is correct, without a formal specification?
  - Automated driving has enough uncertainties (e.g. Black Swans)
  - We should strife for elimination of vagueness and uncertainties where possible

Retargetable Translator



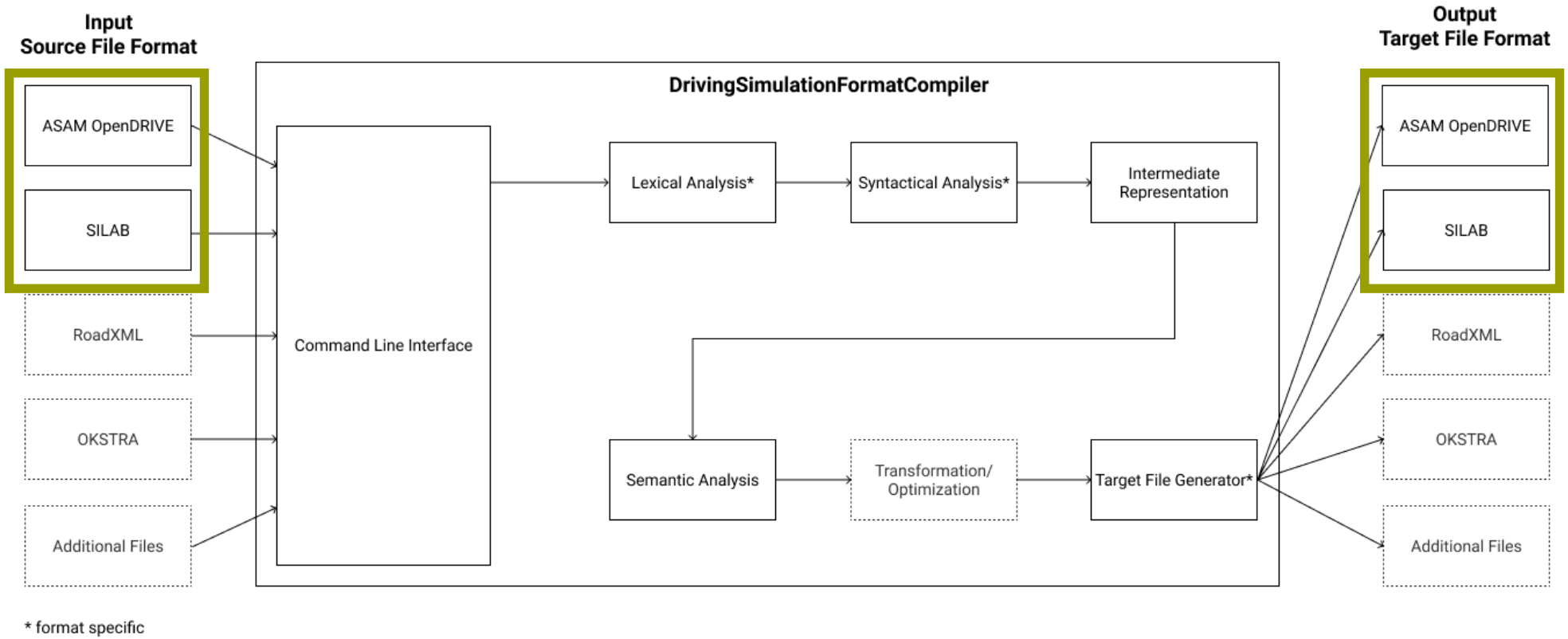
* format specific

Retargetable Translator



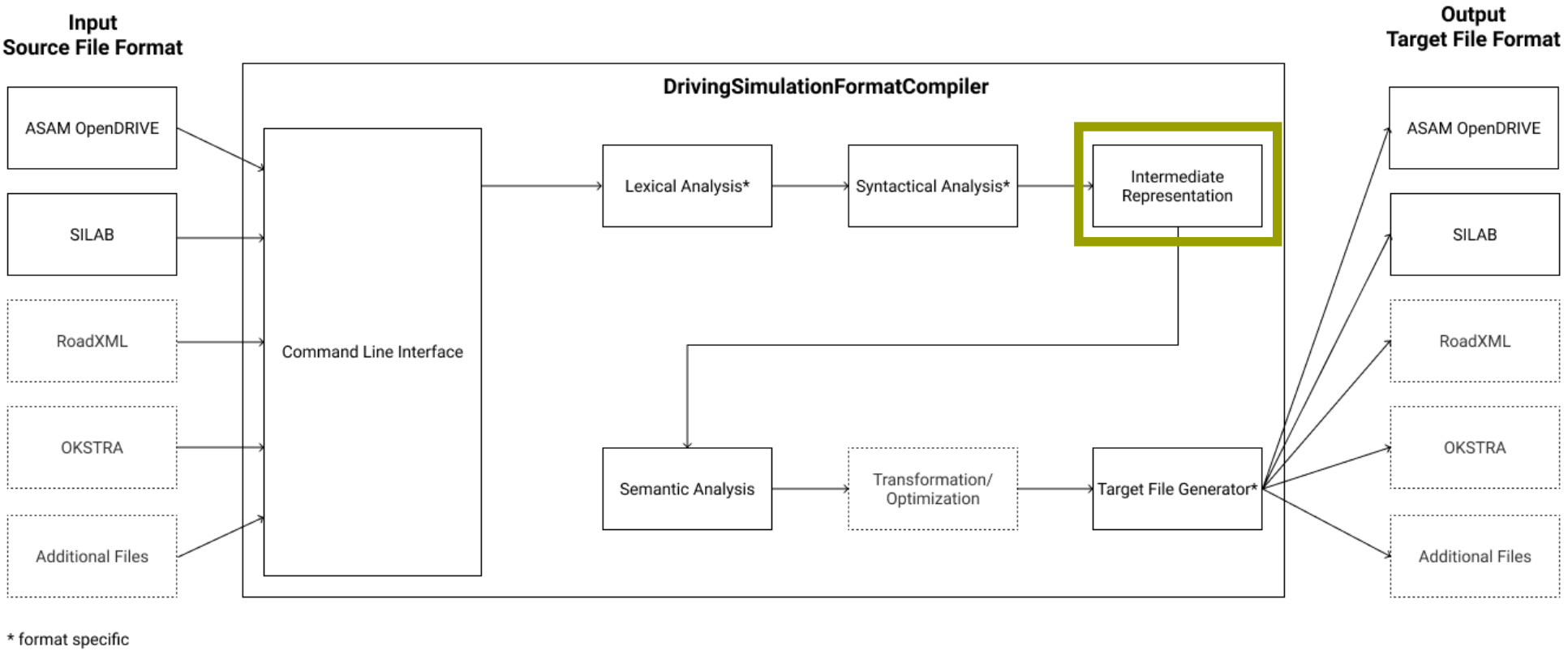
* format specific

Retargetable Translator



* format specific

Retargetable Translator



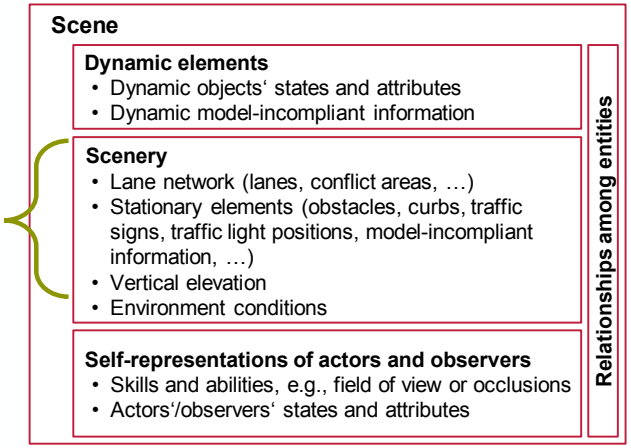
* format specific

Current Focus

- Languages/Formats:
  - SILAB (WIVW GmbH)
  - ASAM OpenDrive
  - OKSTRA
- Simulated Objects/Aspects
  - Road Network
  - Stationary Items (e.g. Traffic Signs)
  - Static Properties

Current Focus

- Languages/Formats:
  - SILAB (WIVW GmbH)
  - ASAM OpenDrive
  - OKSTRA
- Simulated Objects/Aspects
  - Road Network
  - Stationary Items (e.g. Traffic Signs)
  - Static Properties



Source: Ulbrich; Menzel; Reschka; Schuldt; Maurer: *Defining and Substantiating the Terms Scene, Situation, and Scenario for Automated Driving*. 2015 IEEE 18th International Conference on Intelligent Transportation Systems. IEEE, Sept. 2015.

Challenge: Semantics

- What is the semantics of road elements in driving simulation?
  - Geometry?
  - Markings?
  - Friction/Roughness?
  - Color?
  - Texture?
  - Reflection characteristic of radar signals?
  - …
- May be a flat model with “exact” and “complete” physical properties?
  - Lacks more abstract aspects (e.g. Traffic Sign)

How is this solved for Programming Languages?

Denotational Semantics:

$$C : \mathbf{Com} \rightarrow (\Sigma \rightarrow \Sigma)$$

Example for Assignment Statement (x:=a):

$$C[\![x := a]\!] = \{(\sigma, \sigma[x/n]) | \sigma \in \Sigma \wedge n = \mathcal{A}[\![a]\!]\}$$

With $\mathcal{A} : \mathbf{AExp} \rightarrow (\Sigma \rightarrow \mathbf{N})$ as semantic function for arithmetic expressions,

and Σ as state space of the executing abstract machine

Abstract Driving Simulator Machine as key to solution?

- Interesting concept from a certain research perspective

- However: Machine Learning Algorithms cannot abstract!
  - Tiny input differences can lead to a major perturbation, e.g. by completely different classifications

Our Approach

- There are (currently) no suitable
  - (universal) abstract driving simulator machines
  - physical property models
- Therefore we *base semantics on translation* itself
- States are sets of language constructs consisting of tokens (keywords), names (identifiers), and attributes (key-value-pairs)
- Denotational semantics provides partial functions describing the effect of the translator input on the translational state

Translation Semantics

- Very Simple Language (VSL), to explain approach:
  - Syntactic Set **Con**:

$$c ::= i(n,a) \mid i(n) \mid i(a) \mid c_0; c_1$$

$$i ::= \textbf{road} \mid \textbf{lane}$$

$$a ::= v \mid v, a$$

  - Example: **road** (MainRoad, (length, 1000), (width, 3), (lanes, 1))

- State Space $\Sigma = \mathcal{P}(S \times T \times A)$
  - S: Identifiers (Strings)
  - T: Keywords (Tokens)
  - A: Attributes (Key-Value pairs)

Translation Semantics Source -> IR

Semantics as partial function:

$$\mathcal{O} : \mathbf{Con} \rightarrow (\Sigma \rightarrow \Sigma)$$

Example: Statement with Identifier and Attribute ➔ Update Attribute, if already known, add to state, otherwise

$$O[\![i(name, v_\alpha)]\!] = \begin{cases} \{(\sigma, \sigma') \mid \sigma' = \sigma[(name, t_i, a[\alpha/v_\alpha])]\} & \text{if } (name, t_i, a) \in \sigma \\ \{(\sigma, \sigma') \mid \sigma' = \sigma \cup \{(name, t_i, a_{t_i}^0[\alpha/v_\alpha])\} & \text{otherwise} \end{cases}$$

Note:

$$\sigma[(name, t, a[\alpha/v_\alpha])] \text{ is short for } \sigma[(name, t, a)/(name, t, a[\alpha/v_\alpha])]$$

Translation Semantics Source -> IR

Statement with more than one attribute:

$$O[\![i(name, v_{\alpha_1}, \ldots, v_{\alpha_n})]\!] = O[\![i(name, v_{\alpha_2}, \ldots, v_{\alpha_n})]\!] \circ O[\![i(name, v_{\alpha_1})]\!]$$

Statement without attributes:

$$O[\![i(name)]\!] = O[\![i(name, v_{a_{t_i}[1]}, \ldots, v_{a_{t_i}[n]})]\!]$$

Where $v_{a_{t_i}[1]}, \ldots, v_{a_{t_i}[n]}$ are default values

Statement unnamed, with attributes:

$$O[\![i(v_\alpha)]\!] = O[\![i(name', v_\alpha)]\!]$$

With $name'$ as new name

Conclusion and Future Work

- Retargetable Translator for Driving Simulation Languages
  - Currently Supported Languages: SILAB, ASAM OpenDrive
  - Static Items and Properties of Road Networks
- Reflections on Semantics of Driving Simulator Languages
  - Potential Approaches:
    - “Exact” Physical Properties
    - Abstract Driving Simulator Machine
  - Challenging and unsolved issue
- First Translation Semantics for Driving Simulation Languages
  - Allows to reason about correctness of Translation
  - Does not aim at, nor solve the Language Semantics Issue
  - Starting ground for Verification, e.g. following Translation Validation concept

Acknowledgement & Further Details

For an in-depth treatment see:

Schneider, Jörn & Schneider, Marvin, (2022). *A Translation Semantics for Driving Simulation Languages*. In: Michael, J., Pfeiffer, J. & Wortmann, A. (Hrsg.), Software Engineering 2022 Workshops. Bonn: Gesellschaft für Informatik e.V.. (S. 70-81). DOI: 10.18420/se2022-ws-10

Thanks goes to *Marvin Schneider* who implemented the retargetable translator as part of his Master Thesis.

... Thank You for Listening!

Contact: j.schneider@hochschule-trier.de

Trier University
of Applied Sciences

HOCHSCHULE TRIER

FORSCHUNGSVERBUND
VERKEHRSTECHNIK &
VERKEHRSSICHERHEIT