A Domain-Specific Language for Simulation Composition

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Motivation

Approach

Domain Modelling

Example

Conclusion
• Funded by Federal Ministry of Economics and Technology

• E-Mobility in northern Germany (rural area, high share of wind power)

• OFFIS: Simulation based analysis
  • Grid friendly EV charging strategies
  • Increased PV integration in the low voltage grid
  • ...

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Models for
- Electric vehicles (EV)
- Industrial and residential loads
- Photo-voltaic systems (PV)
- Different power grids

Vehicle charging strategies must be developed and tested in different scenarios with varying...
- model configurations (e.g. EV charging power, ...) 
- numbers of models 
- placement of models in the power grid
Find a solution that allows to specify the different scenarios in a flexible and understandable way.
6 Simulation platform

Scenario definition

Composition + Execution

Analysis

Configuration

Modell A

Modell B

Results

Client

Server
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Conclusion
A DSL is a language that has been designed for a specific problem domain

(in contrast to a general purpose language)
9 DSL: What are the benefits?

- Reduced code size and complexity due to specificity
- Increased productivity
- (Easy to understand for domain experts)
- Domain aspects can be implemented independently of the actual system (or its language)
3-level process similar to Model-Integrated Computing  [SK 97]

**Metalevel process (Software engineers)**
- Formal domain modeling
- Model interpreter specification

**System development process (Domain engineers)**
- Model specification
- Model validation

**Usage of the final software**
- Generated from model specification or
- Interpretation of model specification

• Xtext is an **open-source** framework for developing DSLs
• Widely **established, easy** to use but still very flexible/powerful
• DSL specific editor with syntax highlighting and auto-completion automatically generated as Eclipse-plugin

**DSL Definition**

ECMS:

'ECMS [year=INT]
(papers+=Paper)+
(tracks+=Track)*;

Paper:

'Paper' name=INT '::title=STRING;

Track:

'Track' name=STRING 'features:'
(papers+=[Paper])+;

**Generated Editor**

ECMS [2011
Paper p35: "A DSL for..."
Paper p79: "Artificial Genes..."

Track "Complex Simulation" features:

  p35
  p79
  Track
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Track "Complex Simulation" features:
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1. Collection of scenarios that need to be simulated
2. Classification contained objects
3. Analysis of object and scenario characteristics
Key aspects identified:

- **Connection points**
  - Specific or randomly chosen

- **Resource groups**

- **Moving resources (EVs)**
16 Power grid topology

CIM Topology File

Extract connection points

Power Grid Model

Topology meta model

Topology definition

#Topology
Name: TestCaseB
RCPs:
- Bus1_C
- Bus2_C
- Bus3_C
- Transformer20kV_C
Simulation definition

- Treated as „black box“
- Can have configuration parameters
- Can contain 1..* models that have
  - configuration parameters
  - 0..* in-/outputs
Simulation definition

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  - configuration parameters
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Simulation meta modell

Simulation definition
DSL Overview

- Topology meta model
  - Topology definition
    - Simulation meta modell
      - Simulation definition
DSL Overview

Topology meta model

Topology definition

Simulation meta modell

Simulation definition

Scenario meta modell

Scenario definition
DSL Overview

Topology meta model

Simulation meta modell

Simulation-definition

Scenario meta modell

Scenario-definition

Simulation-plattform

Topology definition
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Conclusion
Example

- Low voltage distribution grid
• Low voltage distribution grid
• Groups of private homes with photovoltaics and an EV
• EVs leave grid when driving to work
Example

- Low voltage distribution grid
- Groups of private homes with photovoltaics and an EV
- EVs leave grid when driving to work
- Some business loads
Example: Simulation & Model definition

Simulation EVSim of resource with Parameters
  sim:simulationEnd
  sim:simulationStart

containing Model EV of 1..* instances

Parameters
  random_seed as int
  trip_generator as string
  p_crg as float:Consumption //kWh/100km
  e_bat as float:Energy //kWh
  soc_init as float:EnergyLevel //%

Outputs
  p_vehicle as float:ActivePower, //kW
  float:ReactivePower //kW
  location as string:LocationType
  soc as float:EnergyLevel //%
  distance as float:Distance //km
  plugged_in as boolean
Scenario example1

GlobalParameter
  simulationStart = "01.11.2009"
  simulationEnd = "08.11.2009"

[Parameter specification (see next slide)]
Simulation Parameter Set evsim_params for simulation EVSim with
Model Parameter Set slow_charging_evs for model EV with parameters
Example: Parameter specification

Simulation Parameter Set evsim_params for simulation EVSim with

Model Parameter Set slow_charging_evs for model EV with parameters

- e_bat = 31
- p_crg = 3
- trip_generator = "Simple"

Simulation Parameter Set pv_params for simulation PVSim with

Model Parameter Set private_pv for model Photovoltaic with parameters

- PV_Angle = 30
- PV_IMPP = <var_impp>
- PV_Inverter_maxActivePower = 900
- PV_NOCT = 48
- PV_NumberOfModulesPerString = 6
- PV_NumberOfStrings = 1
- PV_UMPP = 23.8
- PV_aP = -0.48

...
Example: Model instantiation

Scenario example1 using topology LowVoltageGrid_1

GlobalParameter
  simulationStart = "01.11.2009"
  simulationEnd = "08.11.2009"

[Parameter specification (see last slide)]
Scenario example1 using topology LowVoltageGrid_1

GlobalParameter

    simulationStart = "01.11.2009"
    simulationEnd = "08.11.2009"

[Parameter specification (see last slide)]

Create 1 instances of csv.commercial1 connected to grid at rcp:6
Create 1 instances of csv.commercial2 connected to grid at rcp:7
Create 1 instances of csv.commercial3 connected to grid at rcp:8
Scenario example1 \(\text{using topology LowVoltageGrid}_1\)

GlobalParameter

\[
\begin{align*}
simulationStart &= "01.11.2009" \\
simulationEnd &= "08.11.2009"
\end{align*}
\]

[Parameter specification (see last slide)]

Create 9 instances of ModelGroup \text{Home\textunderscore EV\textunderscore PV} connected to grid at random RCP
Scenario example1 using topology LowVoltageGrid_1

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simulationStart = "01.11.2009"
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[Parameter specification (see last slide)]

Create 1 instances of csv.commercial1 connected to grid at rcp:6
Create 1 instances of csv.commercial2 connected to grid at rcp:7
Create 1 instances of csv.commercial3 connected to grid at rcp:8

Create 9 instances of ModelGroup Home_EV_PV connected to grid at random RCP
Create 1 instances of csv.private connected to grid at group RCP
Example: Model instantiation

Scenario example1 using topology LowVoltageGrid_1

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simulationStart = "01.11.2009"
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[Parameter specification (see last slide)]

Create 1 instances of csv.commercial1 connected to grid at rcp:6
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Create 1 instances of csv.commercial3 connected to grid at rcp:8

Create 9 instances of ModelGroup Home_EV_PV connected to grid at random RCP
Create 1 instances of csv.private connected to grid at group RCP
Create 1 instances of pv_params.private_pv connected to grid at group RCP
Example: Model instantiation

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[Parameter specification (see last slide)]

Create 1 instances of csv.commercial1 connected to grid at rcp:6
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Create 1 instances of csv.commercial3 connected to grid at rcp:8

Create 9 instances of ModelGroup Home_EV_PV connected to grid at random RCP

Create 1 instances of csv.private connected to grid at group RCP
Create 1 instances of pv_params.private_pv connected to grid at group RCP
Create 1 instances of evsim_params.slow_charging_evs connected to grid at group RCP when location = "home"
Example: Model instantiation

Scenario example1 using topology LowVoltageGrid_1

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[Parameter specification (see last slide)]

Create 1 instances of csv.commercial1 connected to grid at rcp:6
Create 1 instances of csv.commercial2 connected to grid at rcp:7
Create 1 instances of csv.commercial3 connected to grid at rcp:8

Create 9 instances of ModelGroup Home_EV_PV connected to grid at random RCP
  Create 1 instances of csv.private connected to grid at group RCP
  Create 1 instances of pv_params.private_pv connected to grid at group RCP
  Create 1 instances of evsim_params.slow_charging_evs connected to grid at group RCP when location="home"
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• DSL based scenario description has been presented

Advantages

• Specification of small and large scenarios due to power grid topology references and/or random selection
• DSL can act as scenario documentation
• Loose coupling between scenario definition and simulation platform (via generator or interpreter)
• Single point of truth (no more distributed config files)

Limitations/Future work:

• Data and control flow implicit (based on model roles)
• No hierarchical scenarios


Own publications:
