Towards a Runtime Model for SysML

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Introduction

Relationship between SysML and UML

- **UML 2**
  - UML not required by SysML

- **SysML**
  - UML reused by SysML (UML4SysML)
  - SysML extension to UML (SysML Profile)
UML Diagram Types

Diagram Taxonomy

UML Diagram

Structure Diagram
- Class Diagram
- Object Diagram
- Component Diagram
- Composite Structure Diagram
- Package Diagram
- Deployment Diagram

Behavior Diagram
- Activity Diagram
- State Machine Diagram
- Use Case Diagram
  - Interaction Diagram
    - Sequence Diagram
    - Communication Diagram
    - Interaction Overview Diagram
    - Timing Diagram
SysML Diagram Types

Diagram Taxonomy

- **SysML Diagram**
  - **Structure Diagram**
    - Block Definition Diagram
    - Object Diagram
    - Component Diagram
    - Internal Block Diagram
    - Package Diagram
    - Deployment Diagram
  - **Requirement Diagram**
  - **Behavior Diagram**
    - Activity Diagram
    - State Machine Diagram
    - Use Case Diagram
    - Interaction Diagram
      - Interaction Overview Diagram
      - Communication Diagram
      - Sequence Diagram
    - Parametric Diagram
    - Sequence Diagram
      - Communication Diagram
      - Interaction Overview Diagram
      - Timing Diagram
Introduction

Runtime Model

- Enabling runtime analysis
- Bridging the gap between design time models – running application
- Controlling, observing, and adapting the behavior of a system at runtime

Two types of Runtime Models
- Type I: Particular state of a system’s execution at a specific moment (M1)
- Type II: All possible runtime states of all possible systems through interpreting the language semantics (M2)
# Introduction

## Runtime Model

<table>
<thead>
<tr>
<th>M2 Metamodel</th>
<th>M1 Model</th>
<th>M0 System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Place</strong></td>
<td><img src="image" alt="Place" /></td>
<td><img src="image" alt="Place" /></td>
</tr>
<tr>
<td><strong>Arc</strong></td>
<td><img src="image" alt="Arc" /></td>
<td><img src="image" alt="Arc" /></td>
</tr>
<tr>
<td><strong>Transition</strong></td>
<td><img src="image" alt="Transition" /></td>
<td><img src="image" alt="Transition" /></td>
</tr>
<tr>
<td><strong>Token</strong></td>
<td><img src="image" alt="Token" /></td>
<td><img src="image" alt="Token" /></td>
</tr>
</tbody>
</table>

### Structure

- \( t = \{ y \mid (y, t) \in F \} \)
- \( t^* = \{ y \mid (t, y) \in F \} \)

If \( \forall s \in t \, m(s) > 0 \) then

- \( m(s) - 1 \), \( s \in t \), \( s \notin t^* \)
- \( m(s) + 1 \), \( s \notin t \), \( s \in t^* \)

### Behavior

- Conforms to

- Relation of places and transitions

- Mark of places

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**System A** at instant time \( t_1 \)

**System A** at instant time \( t_2 \)
Introduction

fUML

- fUML … Semantics of a Foundational Subset for Executable UML Models

- Runtime Concepts for UML
  - Subset of UML

- SysML a profile of UML

- Specific questions
  - Is it possible to reuse fUML for SysML?
  - How should fUML be extended to handle extensions in SysML?
Uncovering the State of the Art

Methodology

- **Tool Survey**
  - Study offered possibilities in SysML tools regarding simulation

- **Literature Survey**
    - First Analysis and Categorization of papers regarding SysML

- **Tool support**
    - Largest abstract and citation database of peer-reviewed literature
    - Scientific journals, books and conference proceedings
  - Mendeley [https://www.mendeley.com/](https://www.mendeley.com/)
    - free reference manager
SysML Tools

Drawing Tools vs Modeling Tools

- **Drawing Tools**
  - Support for
    - SysML notation (blocks, diamond, lines, …)
  - No support for
    - Enforcement of syntactic (notational) and semantic well-formedness rules
    - Large-scale model management and team modeling
    - Simulations
  - E.g., Visio (Visio Stencils for UML / SysML)

- **Modeling Tools**
  - Capture the functional analysis or architecture of a complex system
  - Support simulations (e.g. Activity and Parametric diagrams)
# SysML tools

## Drawing and Simulation Support

<table>
<thead>
<tr>
<th>Tool</th>
<th>Drawing support for 9 types</th>
<th>State Machine Diagram</th>
<th>Activity Diagram</th>
<th>Sequence Diagram</th>
<th>Parametric Diagram</th>
<th>Use Case Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agilian</td>
<td>~</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no simulation but code generation</td>
</tr>
<tr>
<td>Artisan Studio / PTC</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Link to e.g. Matlab, Modelica, Simulink, IBM Rational DOORS</td>
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<tr>
<td>Astah</td>
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<td></td>
<td></td>
<td></td>
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<tr>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magic Draw Cameo Toolkit</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modelio*</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>no simulation</td>
</tr>
<tr>
<td>Papyrus*</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>no simulation, module Moka (simulation fUML)</td>
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<tr>
<td>Rational Rhapsody</td>
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<tr>
<td>SysML Designer*</td>
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<td></td>
<td></td>
<td></td>
<td>no simulation</td>
</tr>
</tbody>
</table>

* Open Source Programs
Literature Study

Procedure

1. Scopus
   - key phrase: „SysML“

2. 1092 results
   - deletion of papers without author

3. 856 results
   - add in Mendeley

4. 856 results
   - search for duplicates and delete them

5. 845 results
   - analyzing abstracts and identify categories

6. Use categorization
   - create charts
Literature Study

Results

- Papers regarding SysML

![Number of Papers per Year](chart.png)

- Yearly distribution of papers regarding SysML, with a peak in 2012.
Literature Study

Results

- Pattern for simulating SysML models [Nikolaidou 2015]
  - Based on analyses of different simulation approaches
  - Following methodology most often used
    1. Define specific profile
    2. Transform SysML models to simulation models
    3. Use output to validate models

![Use of tools regarding to SysML](image-url)
Further steps

- Cooperation Institute for Production Engineering and Laser Technology
  - Illustration of a basic MES (Manufacturing Execution System) use case
  - Real-world SysML reference model for the production domain

- Tool analysis
  - Implementation of the reference model in various tools
  - Focus: Simulation support
    - Simulate diagrams in isolation
    - Simulate combinations of diagrams

- fUML & SysML
  - Experiments for reusing fUML for SysML models based on Moliz http://www.modelexecution.org/

- Extend the mapping study
  - In-depth survey of 10 years of SysML
  - Publish results for community as for Schema Evolution Survey* by [Rahm2006]

* http://se-pubs.dbs.uni-leipzig.de
References

SysML Tools

References