SysML – a modeling language for Systems Engineering

IDA - Dansk Selskab for Datateknik Konference
19. November 2009
Finn Overgaard Hansen
foh@iha.dk
Ingeniørhøjskolen i Århus

Agenda

- Systems Engineering and SysML
- What is SysML?
- New SysML concepts and diagrams
- Perspectives for SysML
Systems Engineering

According to INCOSE:
“Systems Engineering is an engineering discipline whose responsibility is creating and executing an interdisciplinary process to ensure that the customer and stakeholder’s needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system’s entire life cycle”

INCOSE: The International Council on Systems Engineering
Founded in 1990, 6720 members in dec. 2008

Systems Modeling

[Diagram showing the relationship between requirements, functional/behavioral model, performance model, system model, structural/component model, and other engineering analysis models]
Model Based Systems Engineering (MBSE)

- From document-based to model-based approach
- A model-based approach requires modeling concepts and tools
- MBSE: producing and controlling a coherent System Model
- SysML is created to realize an MBSE approach based on a System model of the wanted system
- SysML is a modeling language not a System Engineering process

What is SysML?

- A graphical modeling language created in response to the UML for Systems Engineering RFP developed by the OMG and INCOSE.
  - a UML Profile that represents a subset of UML 2 with important extensions
- Supports the specification, analysis, design, verification and validation of systems that include hardware, software, data, personnel, procedures, and facilities
- Supports model and data interchange via XMI
SysML Specification History and Status

- **March 2003**: The UML for Systems Engineering RFP (Request for Proposal) was developed jointly by OMG and INCOSE
  - The SysML specification was developed in response to these requirements by the diverse group of tool vendors, end users, academia, and government representatives
- **Sept. 2007**: OMG SysML v.1.0
- **Nov. 2008**: OMG SysML v1.1
  - (doc.id: formal/2008-11-02, 256 pages)

System Model and SW/HW Components
Comparison of SysML and UML

SysML - a modeling language for Systems Engineering

SysML Diagram Taxonomy

SysML - a modeling language for Systems Engineering
Major Extensions to UML 2.x

- New Diagram Types
  - Requirement Diagram (req)
  - Parametric Diagram (par)
- Structure Diagrams
  - Block Definition Diagram (bdd)
  - Internal Block Diagrams (ibd)
- Activity Diagrams
  - extensions for continuous flow modeling
  - extensions to support control operators

The 4 Pillars of SysML

1: Requirements
2: Structure
3: Behavior
4: Parametrics
1. SysML Requirements

- Requirement Diagram – NEW diagram type
- Graphical visualization of requirements
  - Functional
  - Non-functional
- Requirements can be related to:
  - Other requirements
  - Design elements
  - Test Cases
- Standard stereotypes:
  - derive, satisfy, verify, refine, trace and copy
  - Used for requirement traceability

Requirement Diagram Example
2. SysML Structure

- UMLs class concept is replaced with **Blocks**
- A Block connects to other blocks via **Ports**
- Class diagrams are replaced with **Block Definition Diagrams (bdd)**
- Each Block has a **Internal Block Diagram (ibd)** where the internal parts are connected via ports
  - a replacement for class composite diagrams
- Ports can connect discrete as well as **continuous flows of material or information**
Blocks are Basic Structural Elements

- Provides a unifying concept to describe the structure of an element or system
  - Hardware
  - Software
  - Data
  - Procedure
  - Facility
  - Person

- Multiple compartments can describe the block characteristics
  - Properties (parts, references, values)
  - Operations
  - Constraints
  - Allocations to the block (e.g. activities)
  - Requirements the block satisfies

Block Definition Diagram Example
Internal Block Diagram for Automobile Domain

Block Definition Diagram Example
Internal Block Diagram Example

3. SysML - Behavior

- Activity diagrams are enhanced with new concepts
- Flows can be **continuous** and model information as well as **material flow**
- Control flows are introduced
- Activity can have pins

![Diagram](image)
Activity Diagram Notation

Flows can be discrete, streaming or control

Activity Diagram Example
4. SysML Parametric

- Parametric Diagram – NEW diagram type
- Used to express constraints (equations) between value properties
  - Provides support for engineering analysis (e.g., performance, reliability)
- Constraint block captures equations shown on a bdd
  - Expression language can be formal (e.g., MathML, OCL) or informal
  - Computational engine is defined by applicable analysis tool and not by SysML
- Parametric diagram represents the usage of the constraints in an analysis context
  - Binding of constraint usage to value properties of blocks (e.g., vehicle mass bound to $F = m \times a$)
- Parametric enable integration of engineering analysis with design models
Parametric Diagram - Example

Combining Model-Driven (MDD) and Model Based Design (MBD) in Industrial Machine Control

MDD: Model Driven Development in Rhapsody (IBM)  MBD: Model Based Design in Simulink (Mathworks)
MDD versus MBD Feature Comparison

<table>
<thead>
<tr>
<th>Tool Environment Capabilities</th>
<th>Rhapsody</th>
<th>Simulink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems and Software Development Environment</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mathematical Block Diagram Environment</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>UML 2.1, SysML 2.0 Based Code Generation</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dynamic Controls and Signal Processing Engineering</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Logical Algorithm Development</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Requirements Traceability &amp; Documentation</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Define Physical, Functional &amp; Software Architecture</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>SysML/UML Analysis, Simulation &amp; Test</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Physical/Plant Behavior Modeling</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Table 1. MDD versus MBD feature comparison

### Cross Connecting Model Elements

[Diagram showing structure and behavior connections]

**Structure**
- Allocate
- Value binding
- Verify

**Behavior**
- Allocate

**Requirements**
- Satisfy

**Parametrics**
- [Diagram showing parametric connections]
Vendors of SysML tools

- ARTiSAN Software Tools
- EmbeddedPlus Engineering (Third party for IBM Rational)
- IBM
  - Rhapsody
  - Tau
- InterCAX
- No Magic
- Papyrus for SysML (open source eclipse modeling tool)
- Software Stencils - Microsoft Visio SysML and UML templates
- Sparx Systems

Perspectives for SysML

- Enable a common modeling language and model across engineering disciplines
- Enable traceability between disciplines
- Enable different kinds of system analysis
- Enable integration of discrete and continuous based modeling tools
- Critical enabler for Model Based System Engineering with tool support
Summary

- SysML a common modeling language for different disciplines e.g. Hardware, Software and Mechanic
- New and important concepts for cross disciplinary analysis of system properties (e.g. parametric)
- Blocks and ports as general modeling elements
- Important enhancement to activity diagrams
- Lot of support for traceability between models and model elements
- Must be supported by an appropriate SE process

References

- OMGs SysML homepage: [www.omg-sysml.org](http://www.omg-sysml.org)
- INCOSE organization: [www.incose.org](http://www.incose.org)
- Books: