火龙果•整理
uml.org.cn

An Overview of the SysML-Modelica Transformation Specification

Chris Paredis (Georgia Tech)

Y. Bernard (Airbus), R. Burkhart (Deere & Co),
H. de Koning (ESA/ESTEC), S. Friedenthal (Lockheed Martin Corp.),
P. Fritzson (Linköping University), N. Rouquette (JPL),
W. Schamai (EADS)

SysML-Modelica Transformation Specification: Context & Objective

火龙果•整理
uml.org.cn

- Two complementary languages for Systems Engineering:
  - Descriptive modeling in SysML
  - Formal equation-based modeling for analyses and trade studies in Modelica

- Objective:
  - Leverage the strengths of both SysML and Modelica by integrating them to create a more expressive and formal MBSE language.
  - Define a formal Transformation Specification:
    - a SysML4Modelica profile
    - a Modelica abstract syntax metamodel
    - a mapping between Modelica and the profile

Presentation Overview

火龙果•整理
uml.org.cn

- What is SysML?
- What is Modelica?

- Motivating Example: Design & Analysis of Robot

- SysML-Modelica Transformation Specification
- Transformations in Systems Modeling
- Model reuse and composition
- Summary

What is SysML?

火龙果•整理
uml.org.cn

- The Systems Modeling Language (OMG SysML™) is a *visual, general purpose modeling language*

- ***Is*** a modeling language that provides
  - Semantics = meaning
  - Notation = representation of meaning

- ***Is not*** a methodology or a tool
  - SysML is methodology and tool independent

- Developed by the Object Management Group to support Model-Based Systems Engineering

What Can be Expressed in SysML?

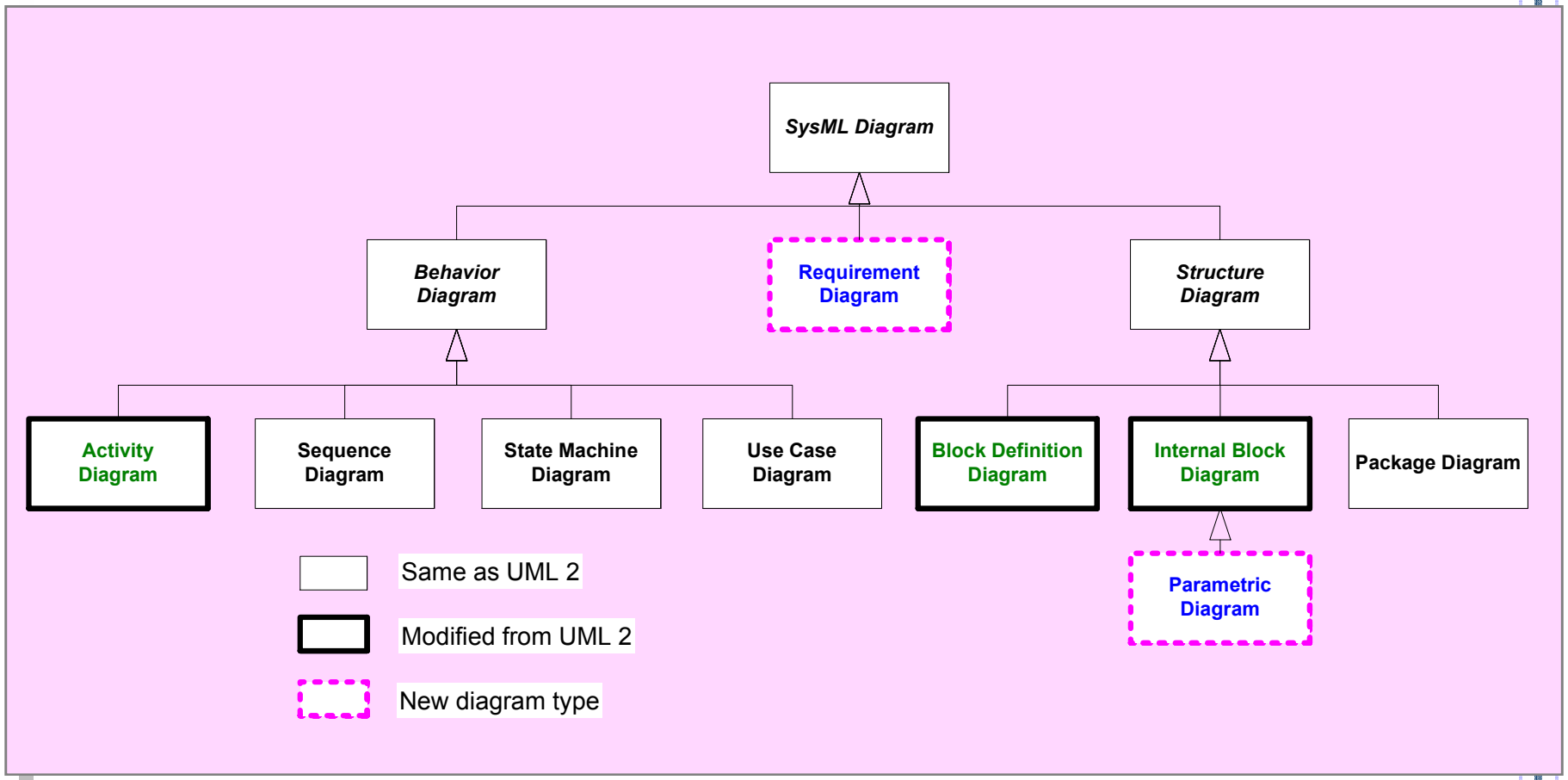
火龙果•整理
uml.org.cn

- SysML is a language to express the information and knowledge generated and processed during the application of a systems development methodology

  - Specification
  - Analysis
  - Design
  - Verification
  - Validation
  - Hardware
  - Software
  - Data
  - Personnel
  - Procedures
  - Facilities

SysML Diagram Taxonomy

火龙果•整理
uml.org.cn



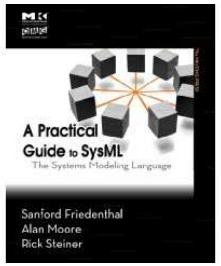
Think of SysML as an integrated collection of languages…

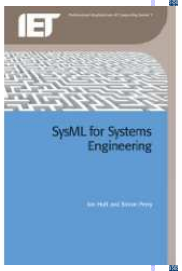
Reprinted with permission. Copyright © 2006-2008 by Object Management Group.

Some History…

火龙果•整理
uml.org.cn

- Specification: http://www.omg.org/spec/SysML/
  - v1.0: 2007-09
  - v1.1: 2008-11
  - v1.2: 2010-06
  - v2.x: RFI preparation workshop - 2008-12
- Strong vendor support
  - MagicDraw (No Magic), Artisan Studio (Atego), Enterprise Architect (Sparx Systems), Rhapsody (IBM),…
- Good learning infrastructure
  - Books, short courses, academic courses, INCOSE/OMG tutorial, public examples, etc.
- OMG Certified Systems Modeling Professional
  - http://www.omg.org/ocsmp/

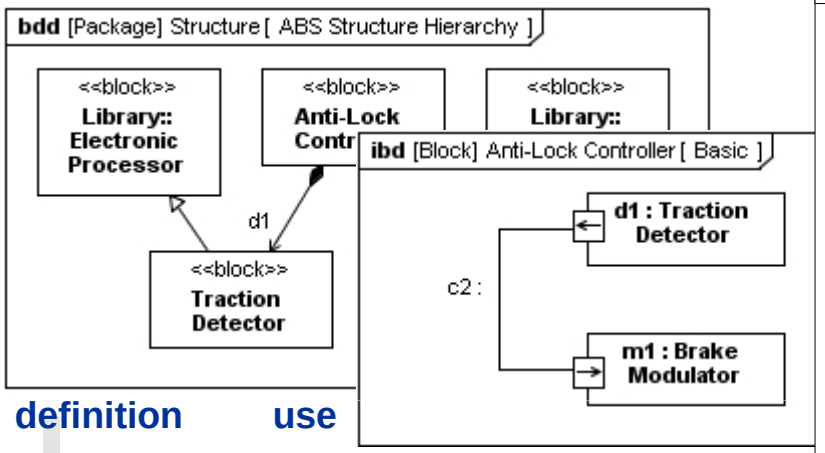




What is SysML? (www.omgsysml.org)

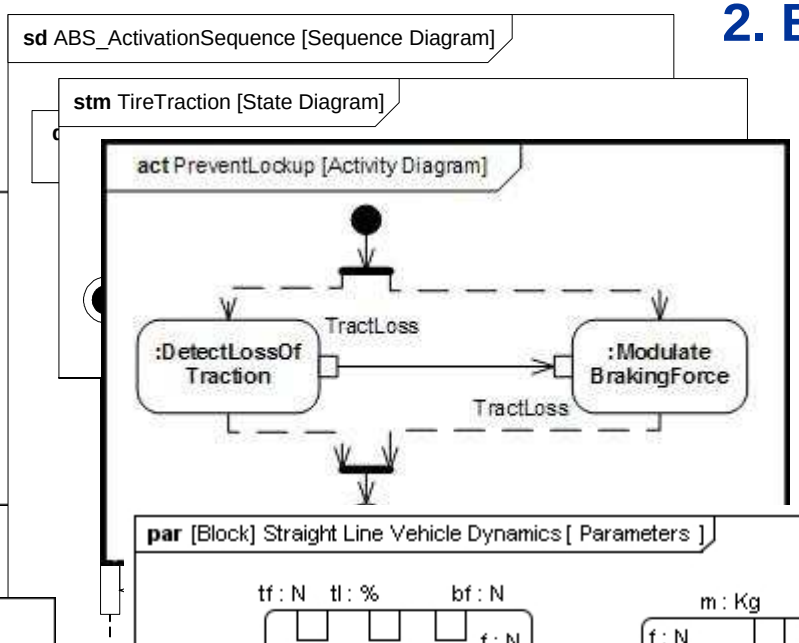
火龙果•整理
uml.org.cn

1. Structure



definition use

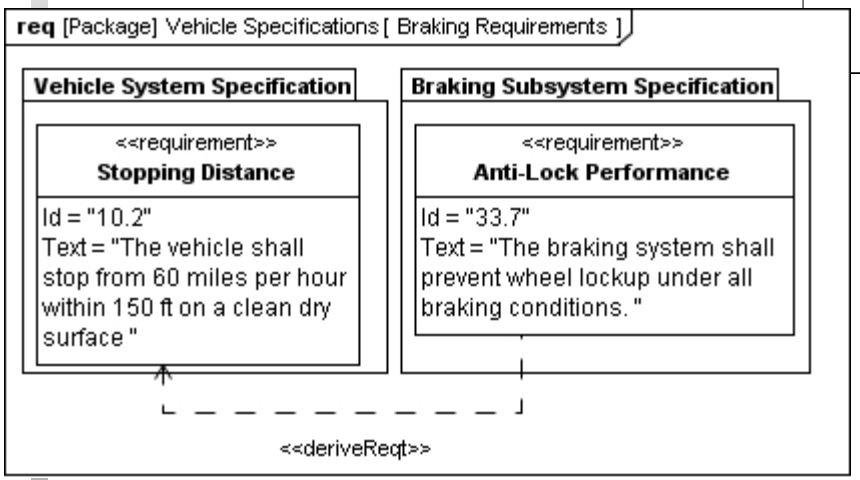
2. Behavior



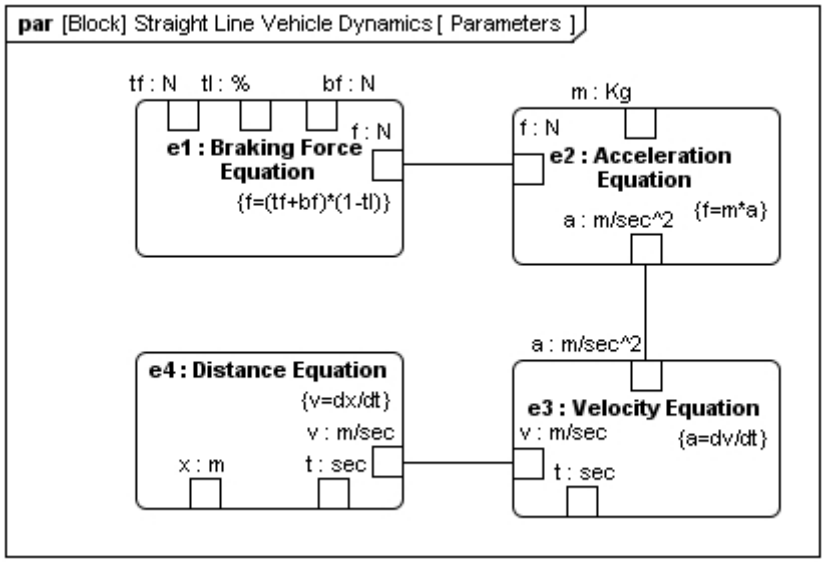
interaction

state machine

activity/ function



3. Requirements



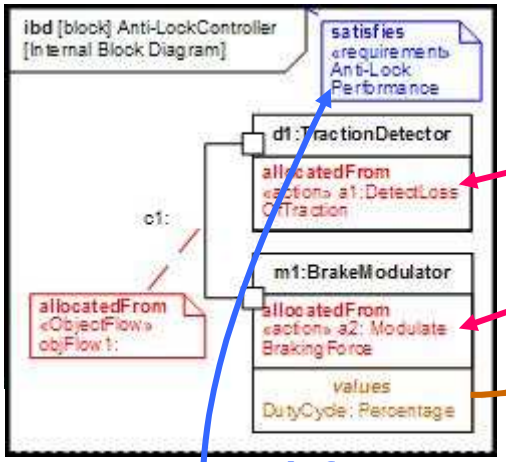
4. Parametrics

101.02SysML Tutorial (June 2008). Reprinted with permission. Copyright © 2006-2008 by Object Management Group.

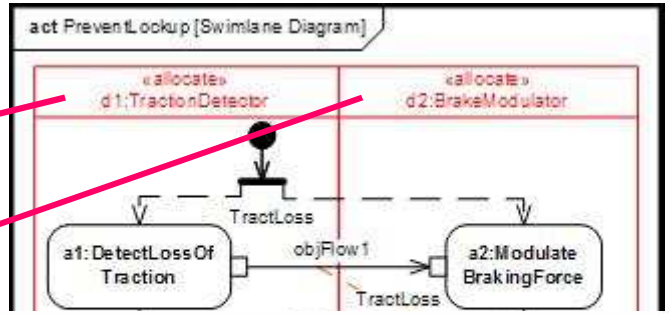
What is SysML? (www.omgsysml.org)

火龙果•整理
uml.org.cn

1. Structure



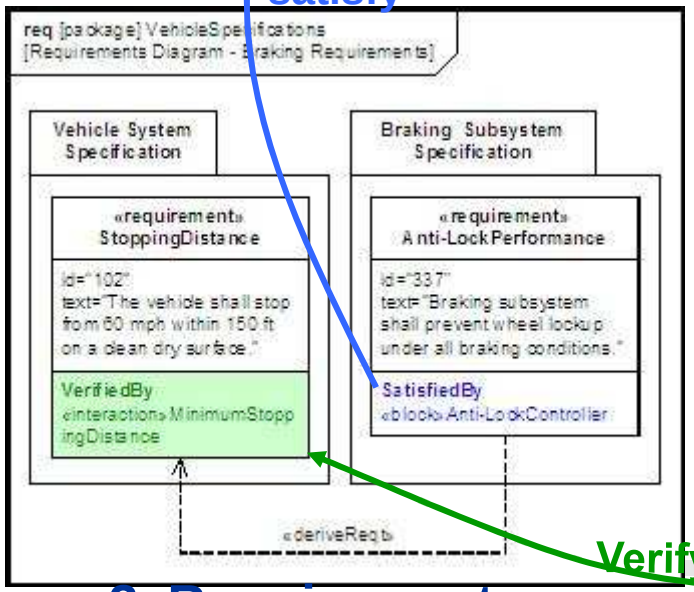
2. Behavior

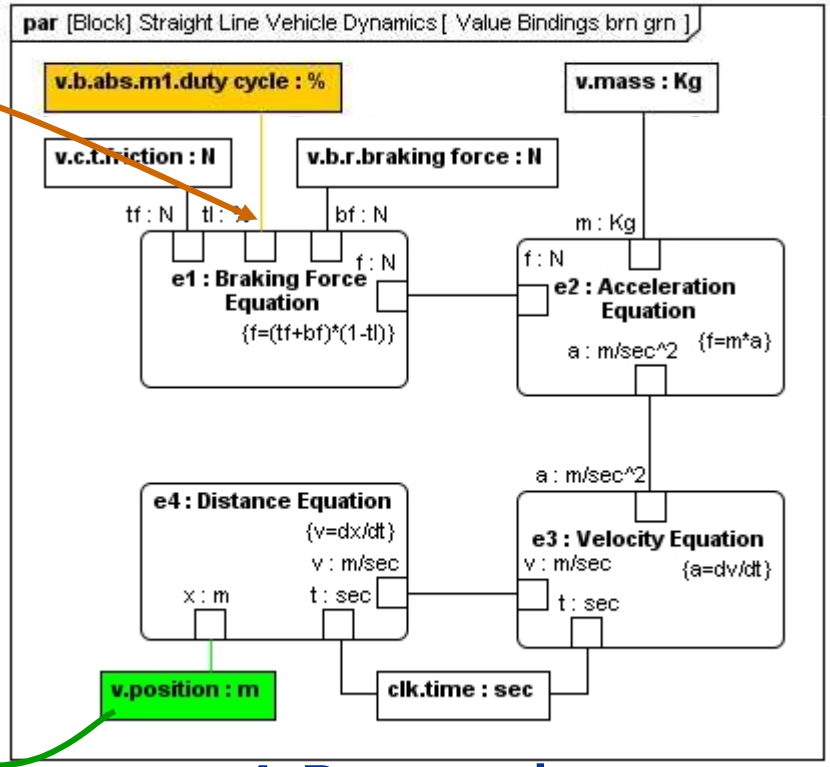


allocate

value binding

satisfy





Verify (via interaction)

3. Requirements

4. Parametrics

101.02SysML Tutorial (June 2008). Reprinted with permission. Copyright © 2006-2008 by Object Management Group.

What is Modelica? (www.modelica.org)

火龙果•整理
uml.org.cn

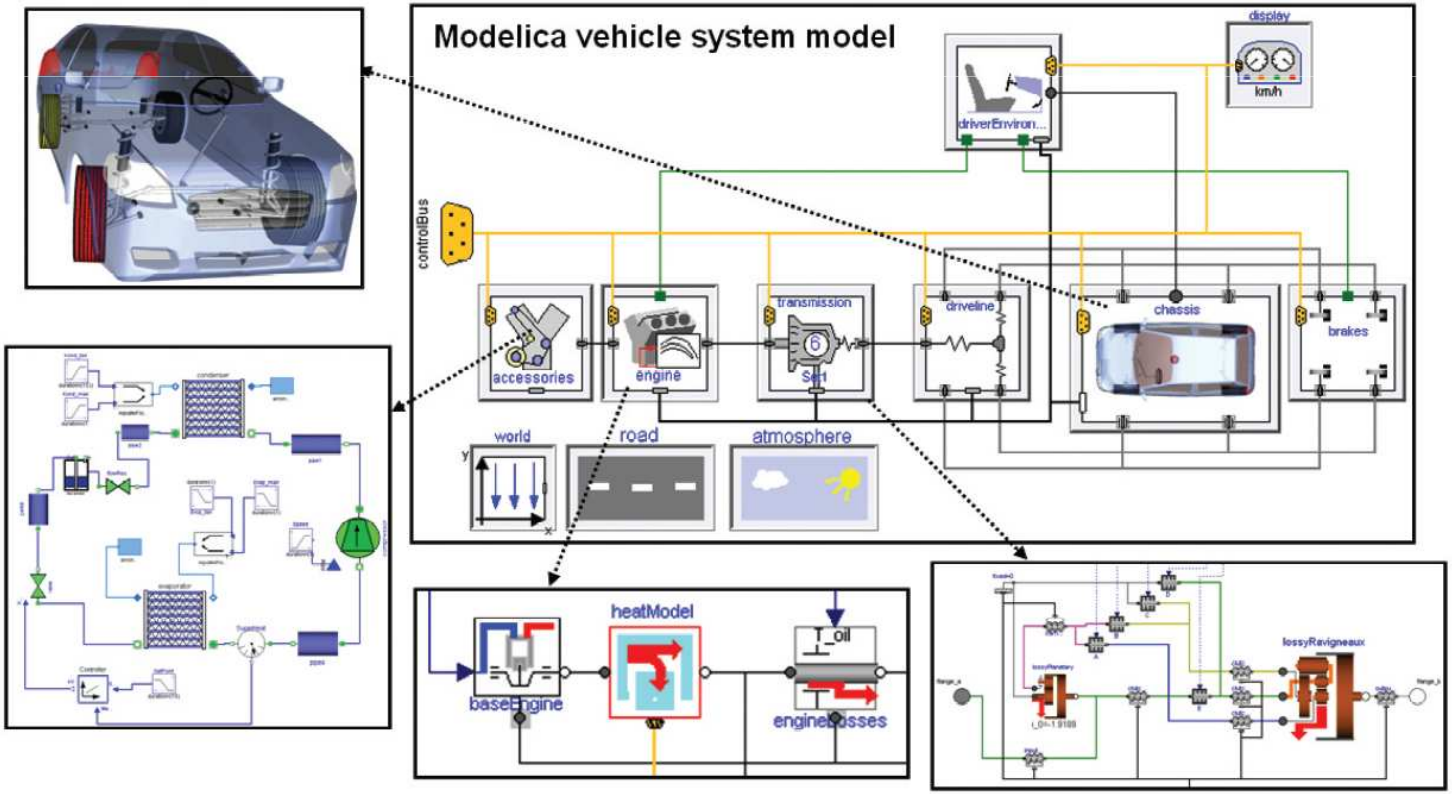
- State-of-the-art Modeling Language for System Dynamics
  - Differential Algebraic Equations (DAE)
  - Discrete Events

- Formal, object-oriented language
- Standardized by the Modelica Association
  - Open language specification – tool independent
- Multi-domain modeling
- Ports represent energy flow (undirected) or signal flow (directed)
- Acausal, equation-based, declarative (f-m*a=0)

Modelica: Active and Mature Communit

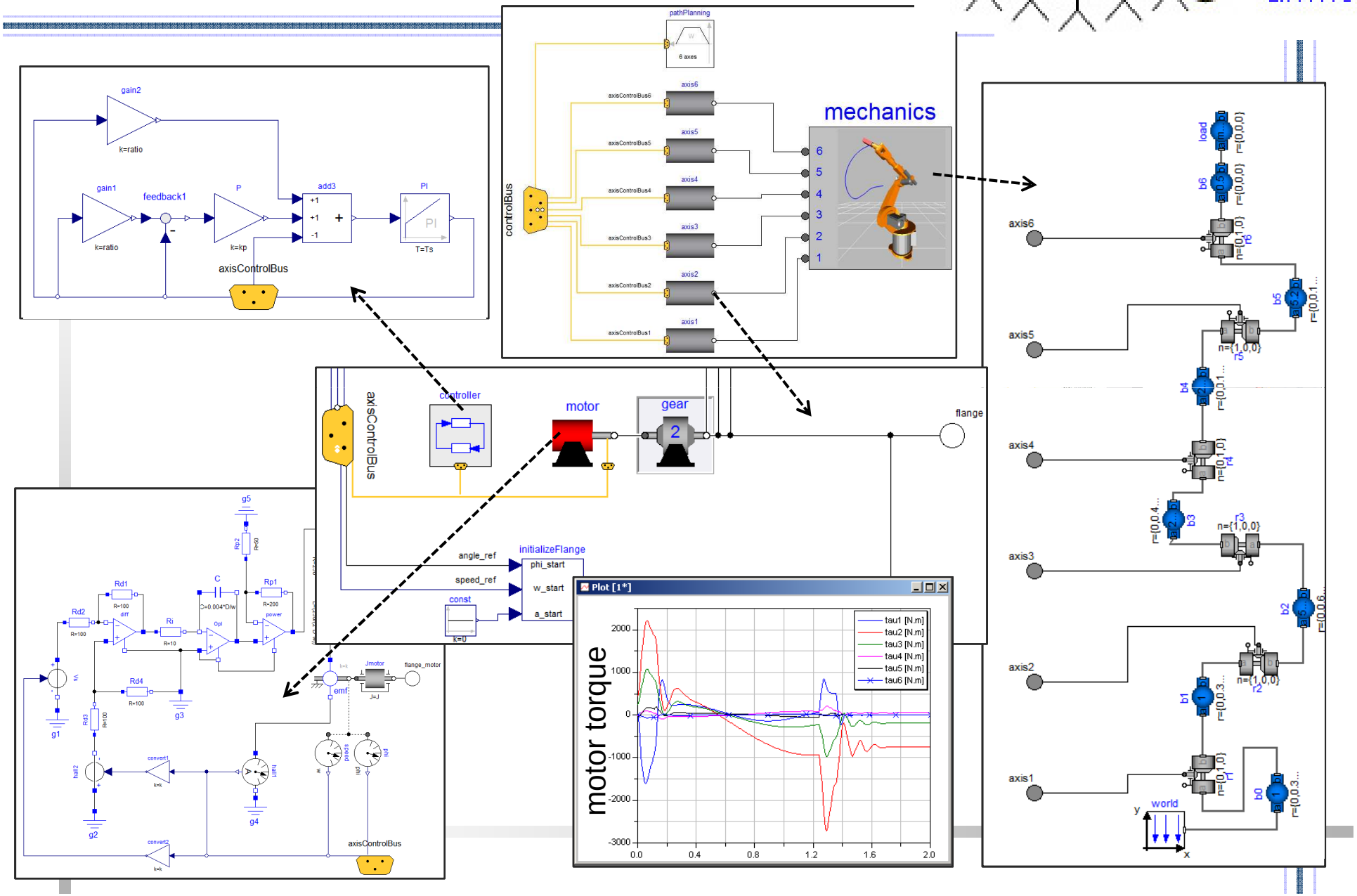
火龙果•整理
uml.org.cn

- Modelica association — 20+ free libs (www.modelica.org)
- 6 commercial solvers, 3 open-source solvers (Dymola, MapleSim, SimulationX, OpenModelica,…)
- EUROSYSLIB project — 20+ libs under development (http://www.itea2.org/public/project_leaflets/EUROSYSLIB_profile_oct-07.pdf)



A Robot Example in Modelica

火龙果•整理
uml.org.cn

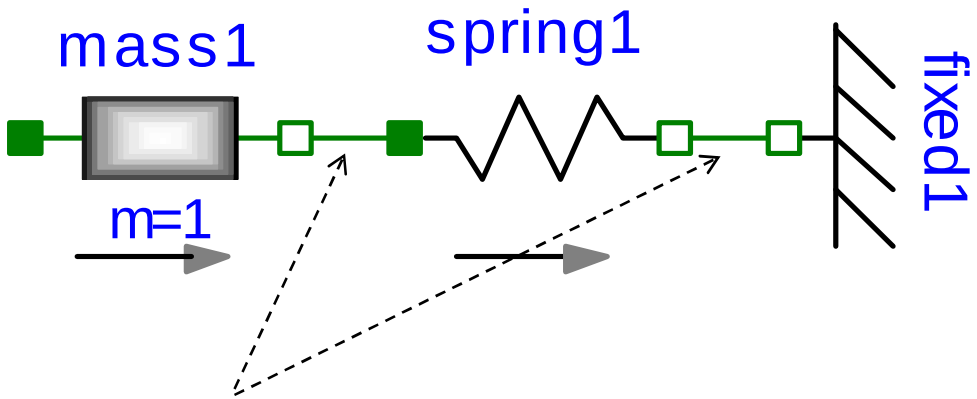


Modelica Semantics and Textual Syntax

火龙果•整理
uml.org.cn

```
model Spring "Linear 1D translational spring"
  extends Translational.Interfaces.PartialCompliant;
  parameter SI.TranslationalSpringConstant c(final min=0, start = 1)
    "spring constant ";
  parameter SI.Distance s_rel0=0 "unstretched spring length";

equation
  f = c*(s_rel - s_rel0);
end Spring;
```



Graphical symbols defined as annotations in textual models

- Connections represent Kirchhoff semantics
  - Across variables (voltage, pressure,…) are equal
  - Through variables (current, flow rate,…) add to zero

Presentation Overview

火龙果•整理
uml.org.cn

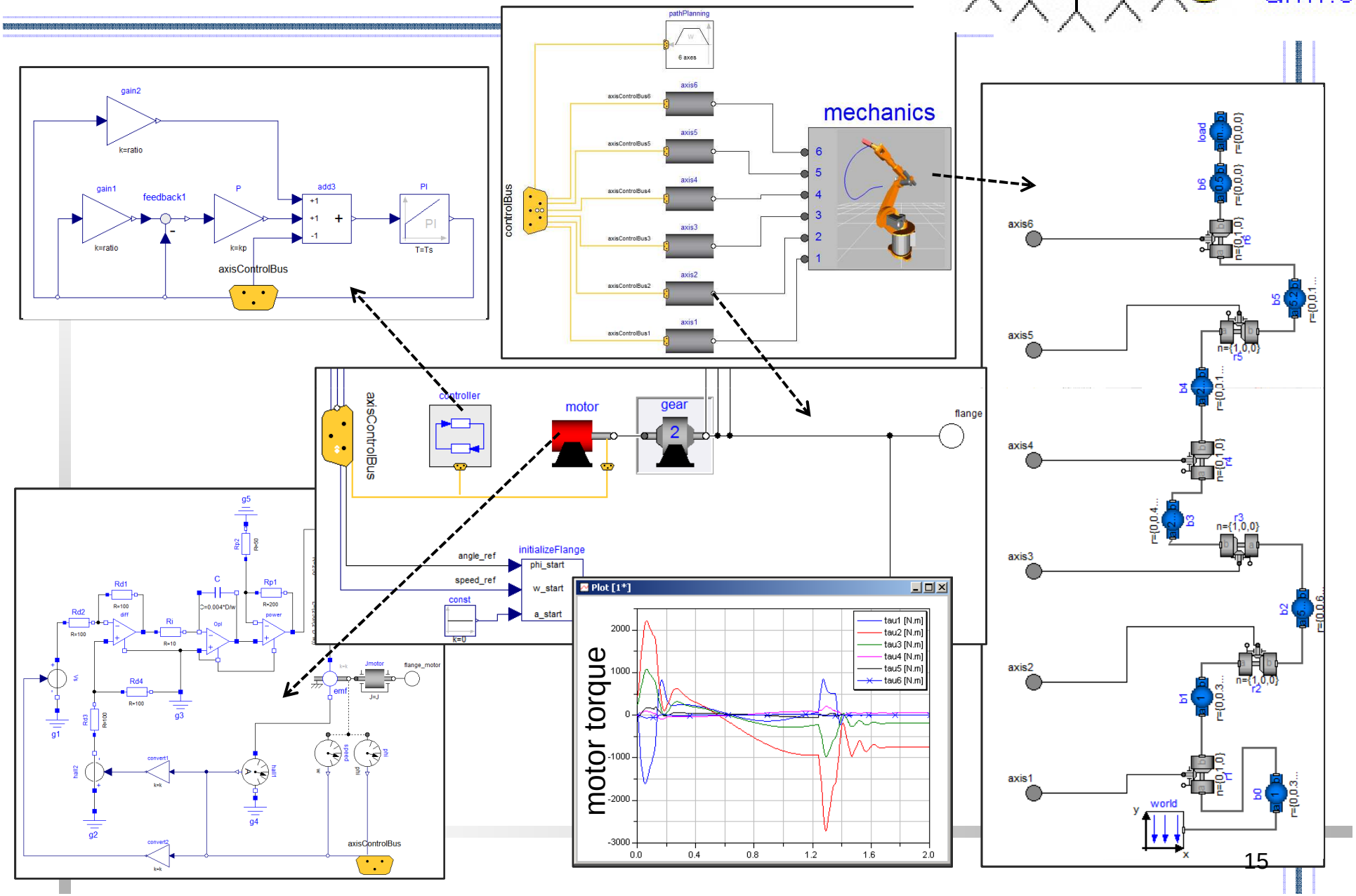
- What is SysML?
- What is Modelica?

- Motivating Example: Design & Analysis of Robot

- SysML-Modelica Transformation Specification
- Transformations in Systems Modeling
- Timeline towards Specification Adoption
- Summary

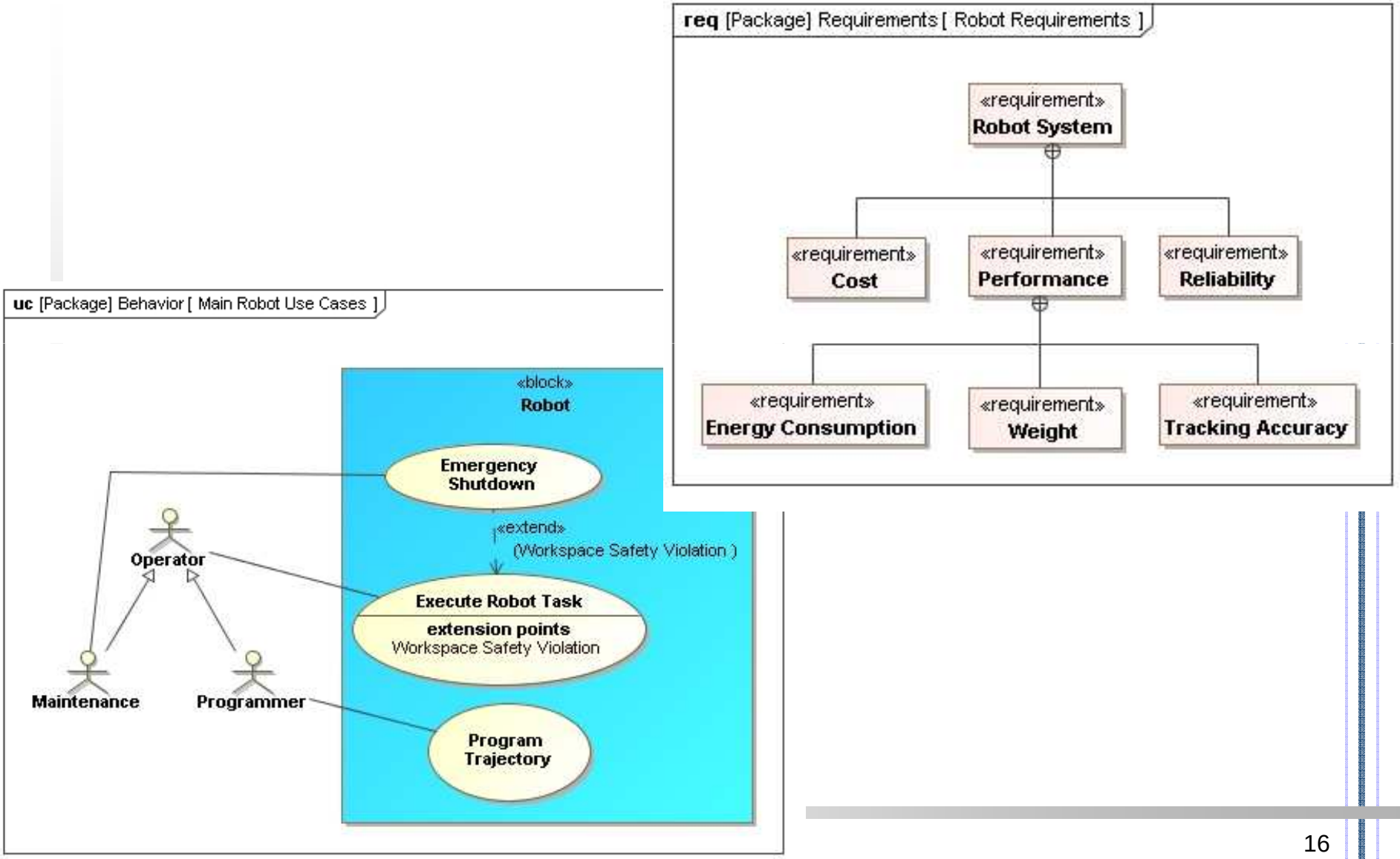
A Robot Example in Modelica

火龙果•整理
uml.org.cn



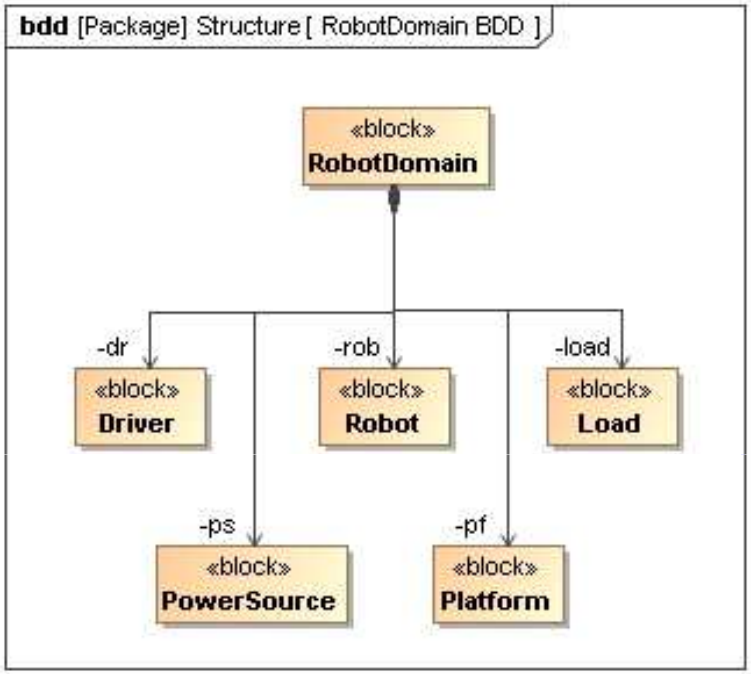
SysML-Modelica Robot Example: UseCases & Requirements

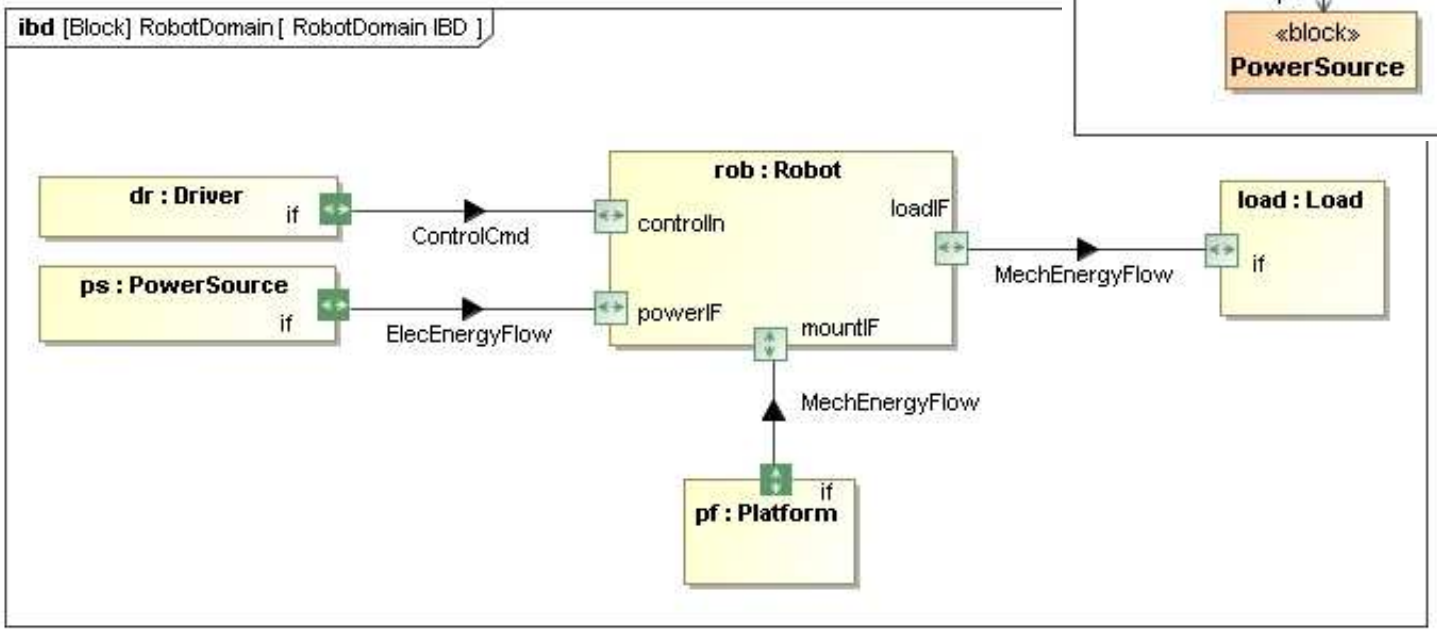
火龙果•整理
uml.org.cn



SysML-Modelica Robot Example: Robot Domain BDD & IBD

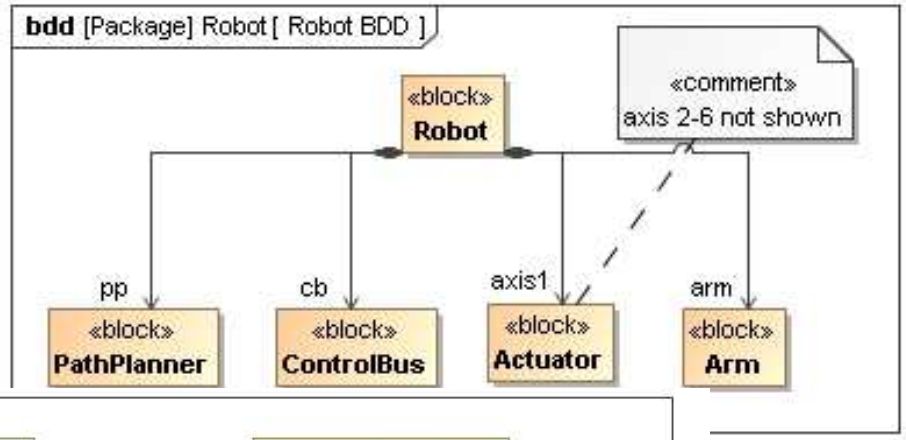
火龙果•整理
uml.org.cn

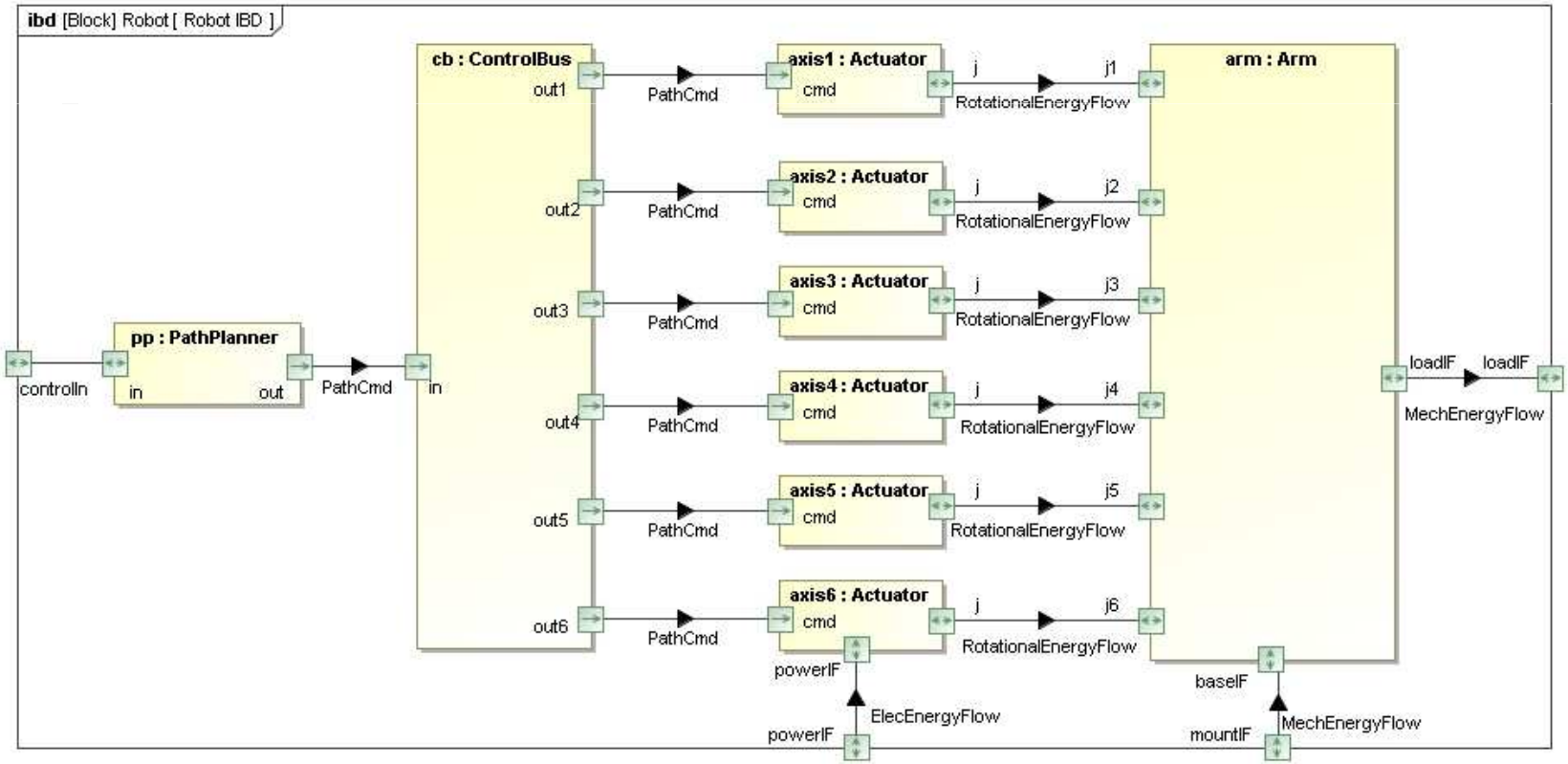




SysML-Modelica Robot Example: Robot BDD & IBD

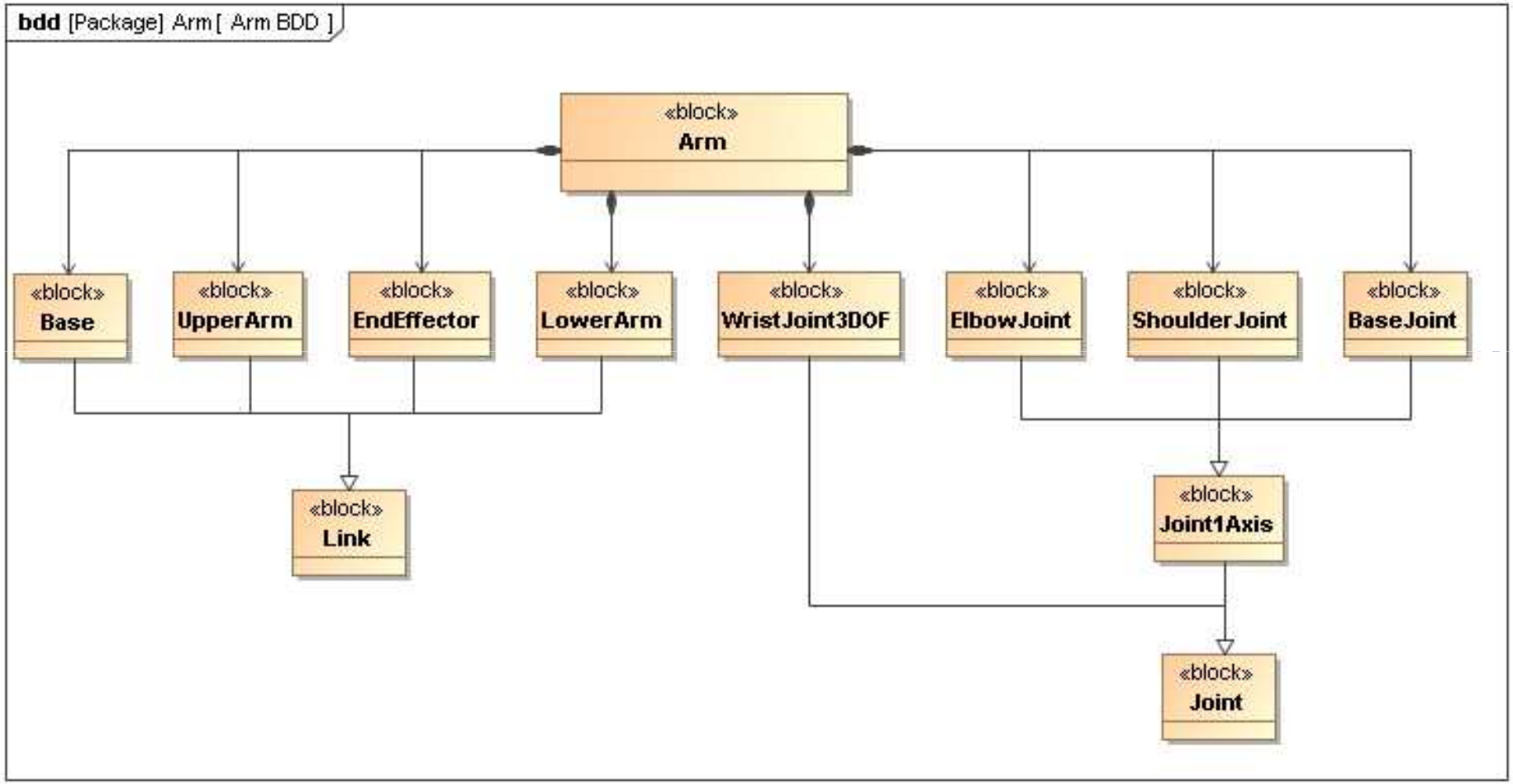
火龙果•整理
uml.org.cn





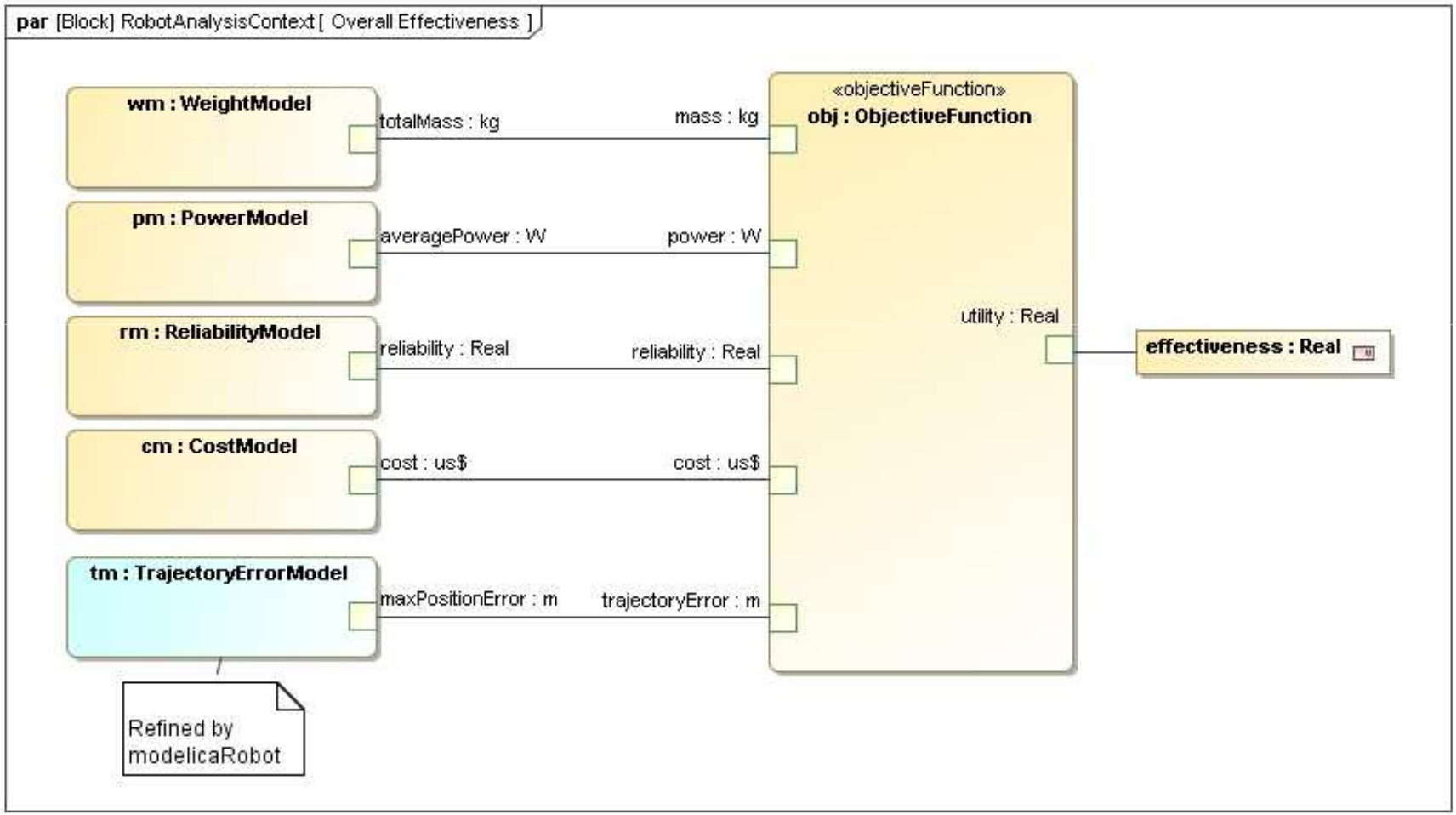
SysML-Modelica Robot Example: Robot Arm BDD

火龙果•整理
uml.org.cn



SysML-Modelica Robot Example: Analysis and Trade Study

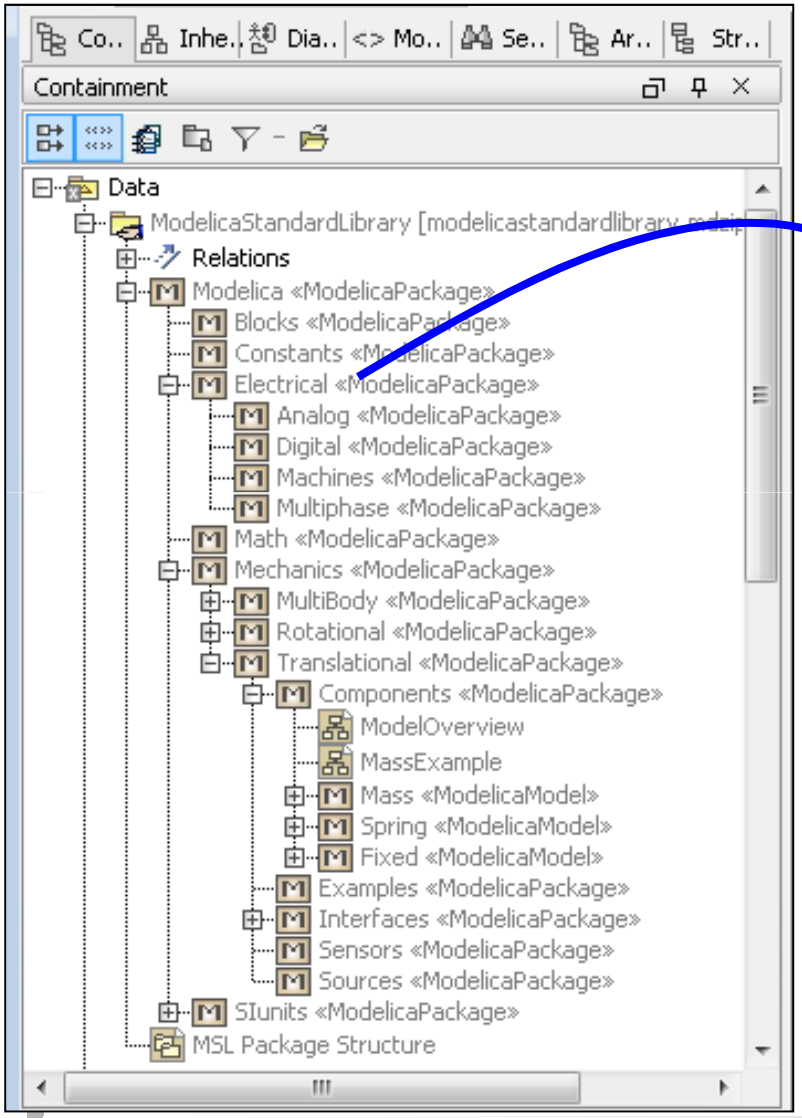
火龙果•整理
uml.org.cn



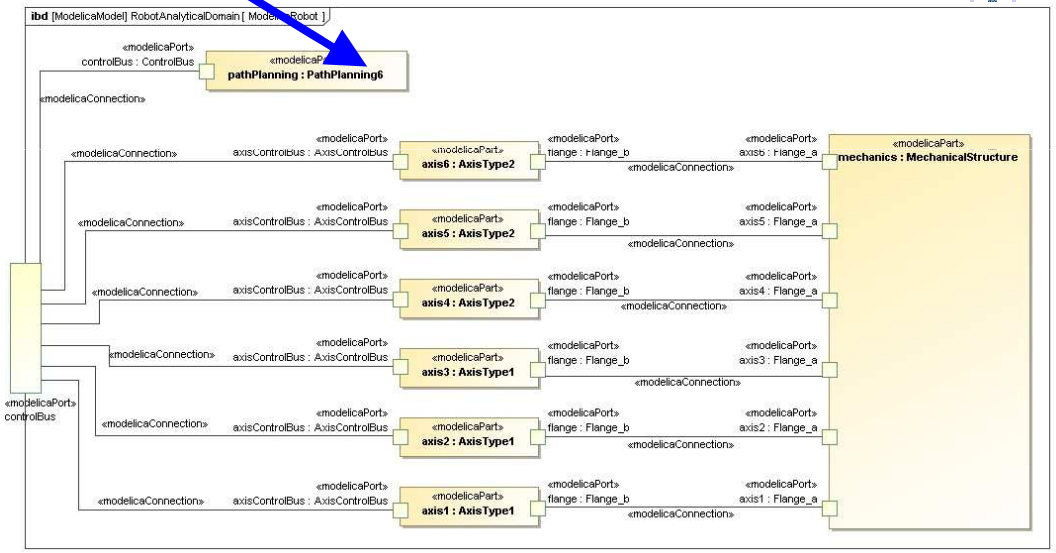
Analysis models depend on descriptive models

SysML4Modelica Analytical Model: Compose Model from Standard Library

火龙果•整理
uml.org.cn

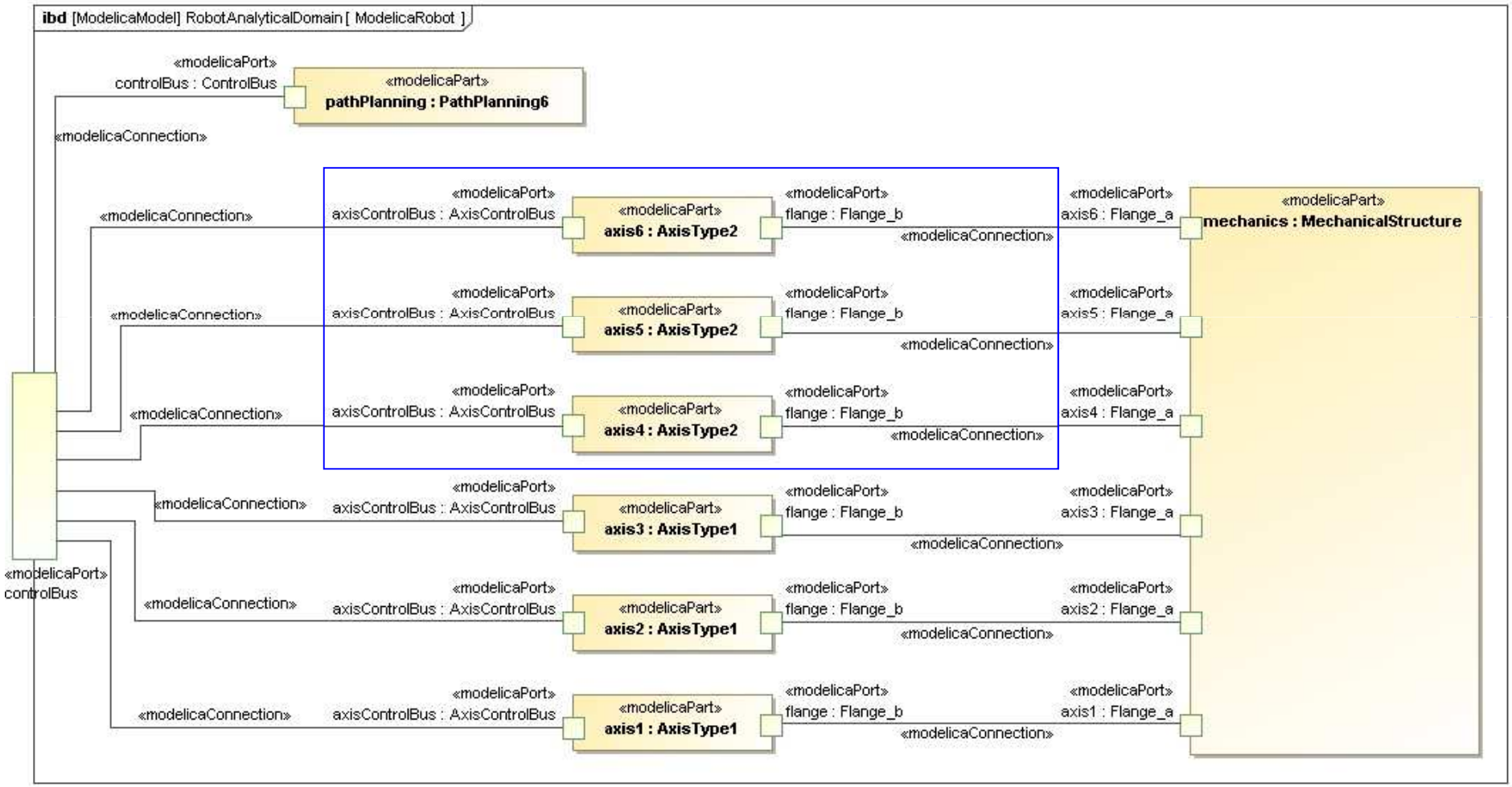


Drag and drop into IBD «ModelicaModel»



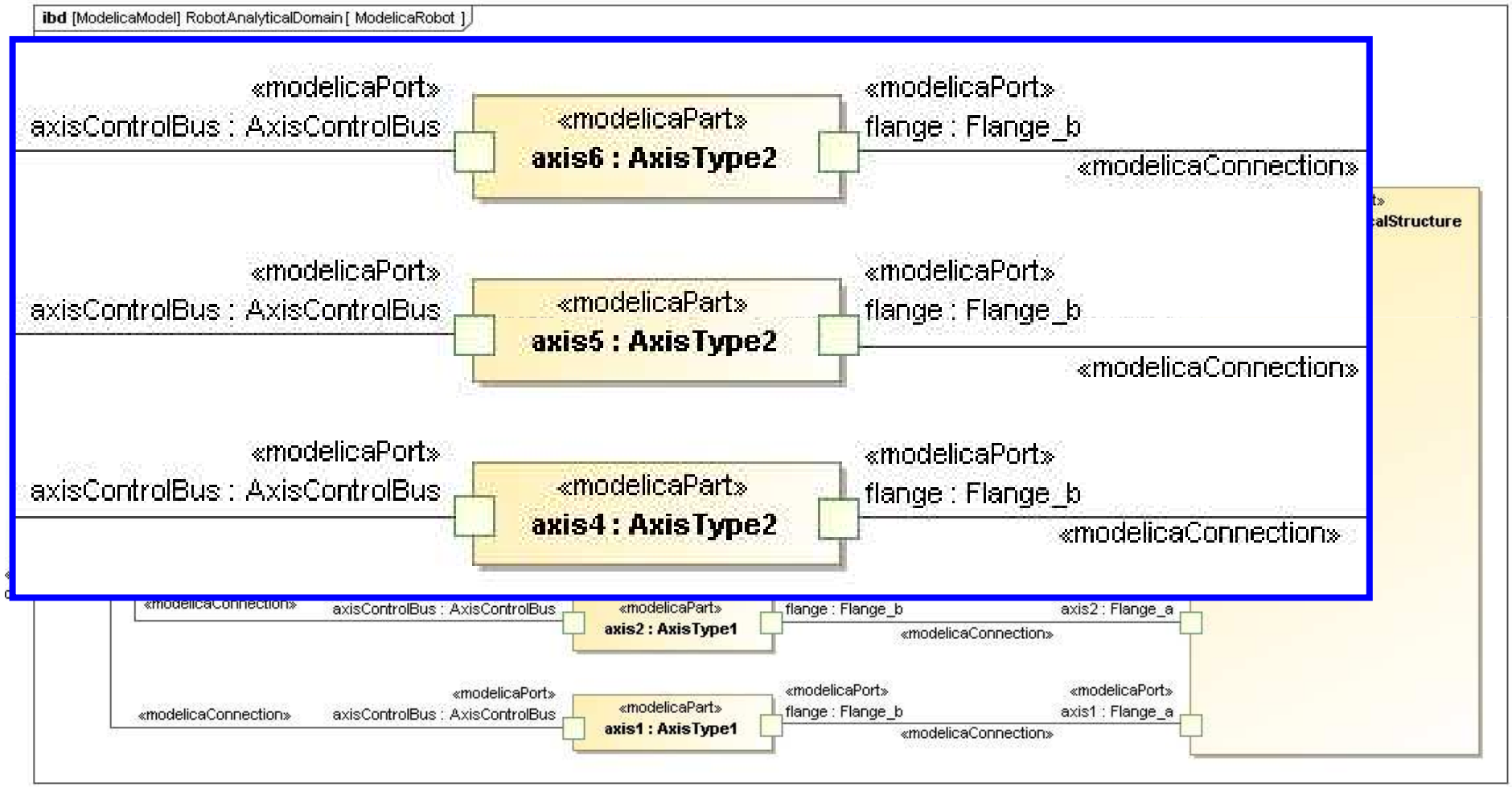
SysML4Modelica Analytical Model: Detailed IBD

火龙果•整理
uml.org.cn



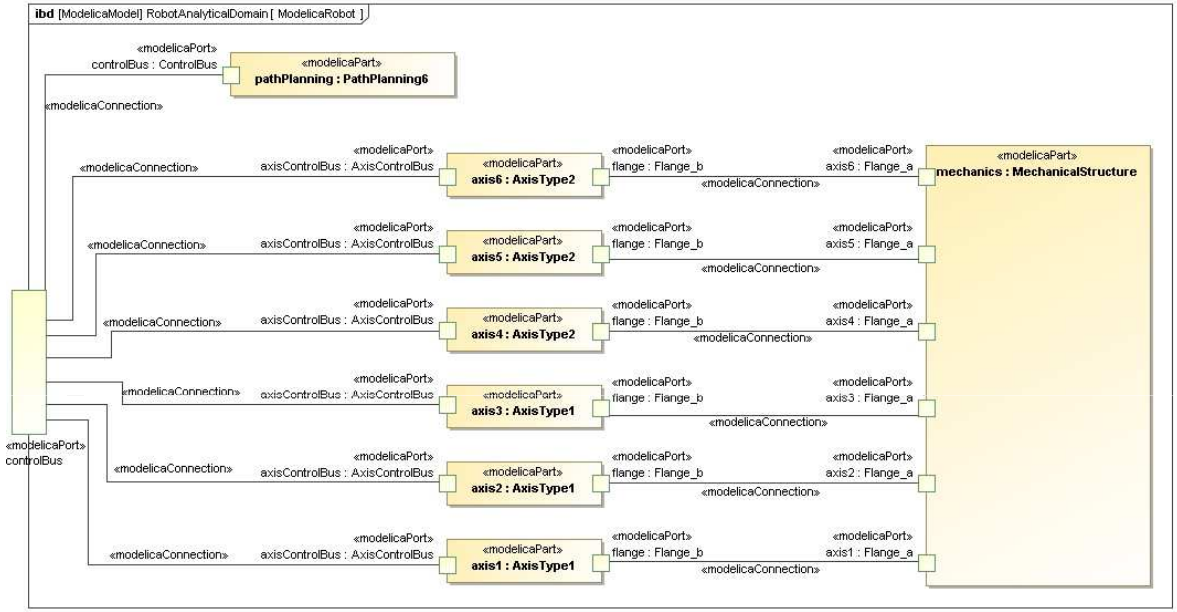
SysML4Modelica Analytical Model: Detailed IBD

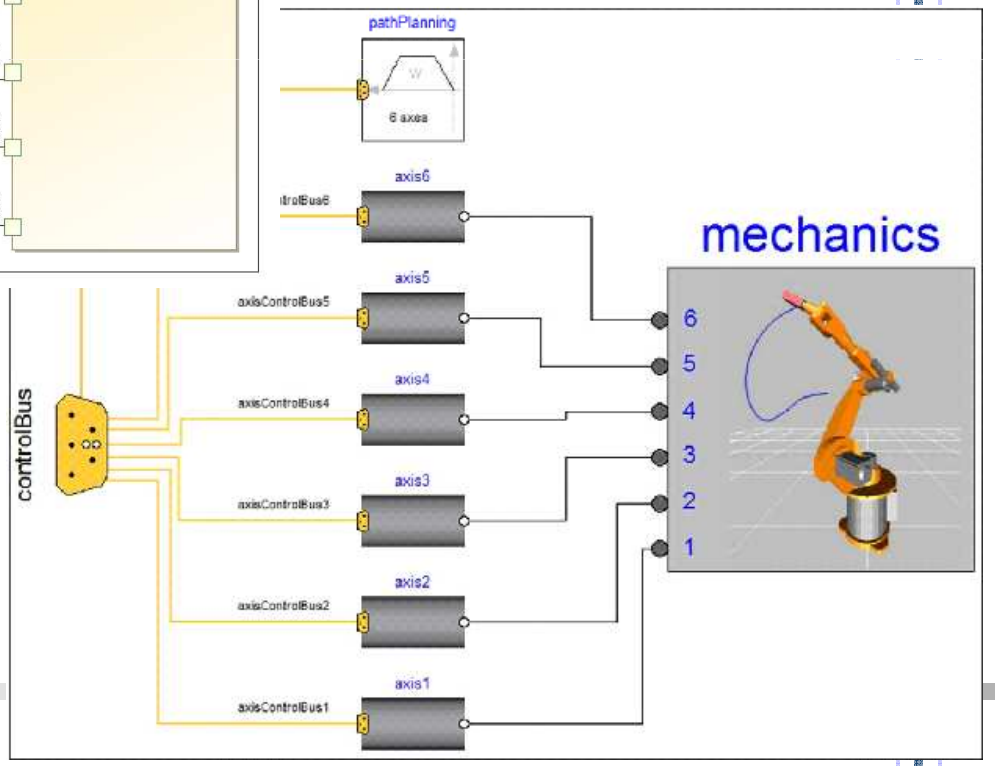
火龙果•整理
uml.org.cn



SysML4Modelica Analytical Model: Relation to Modelica Native Model

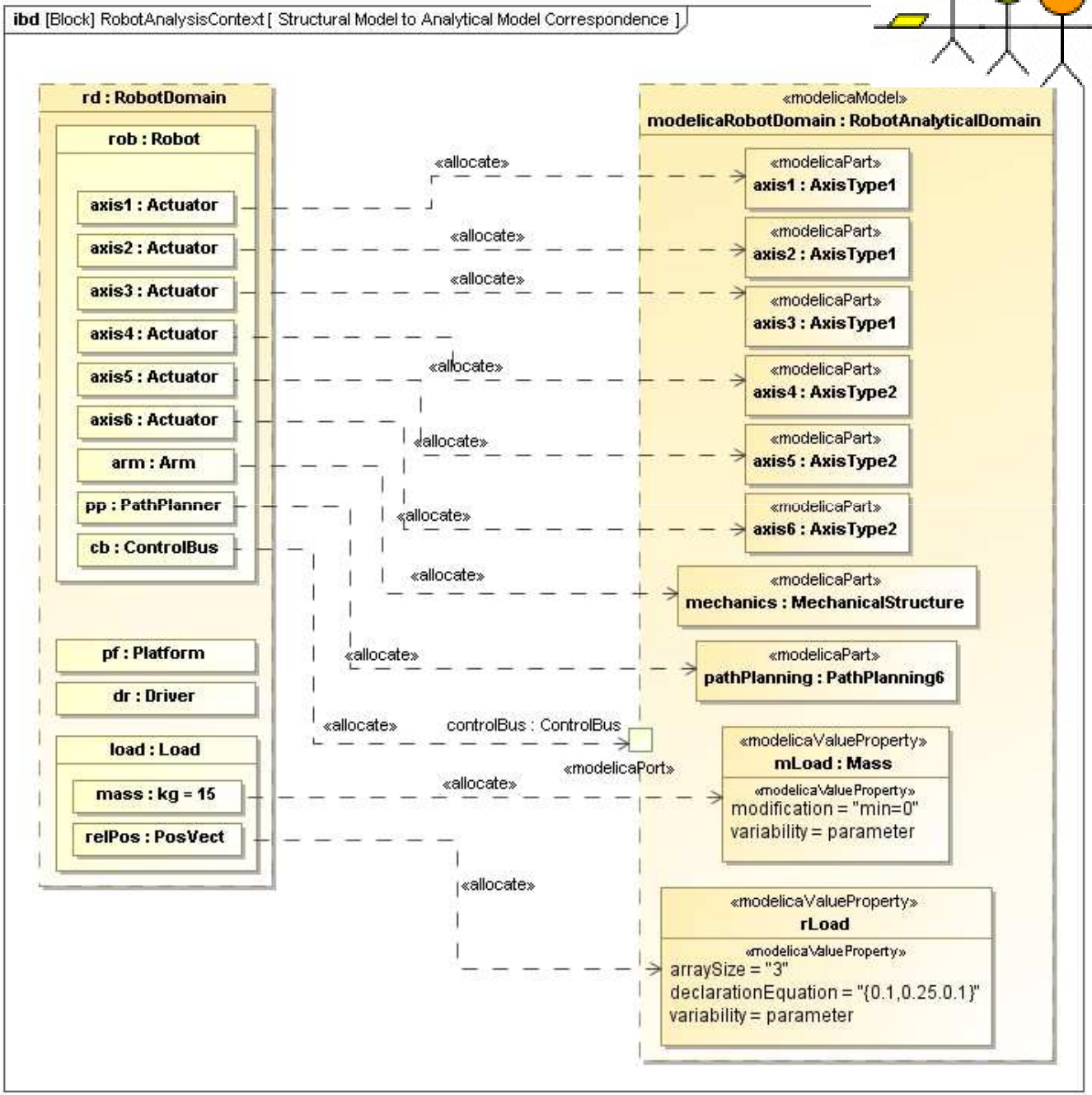
火龙果•整理
uml.org.cn





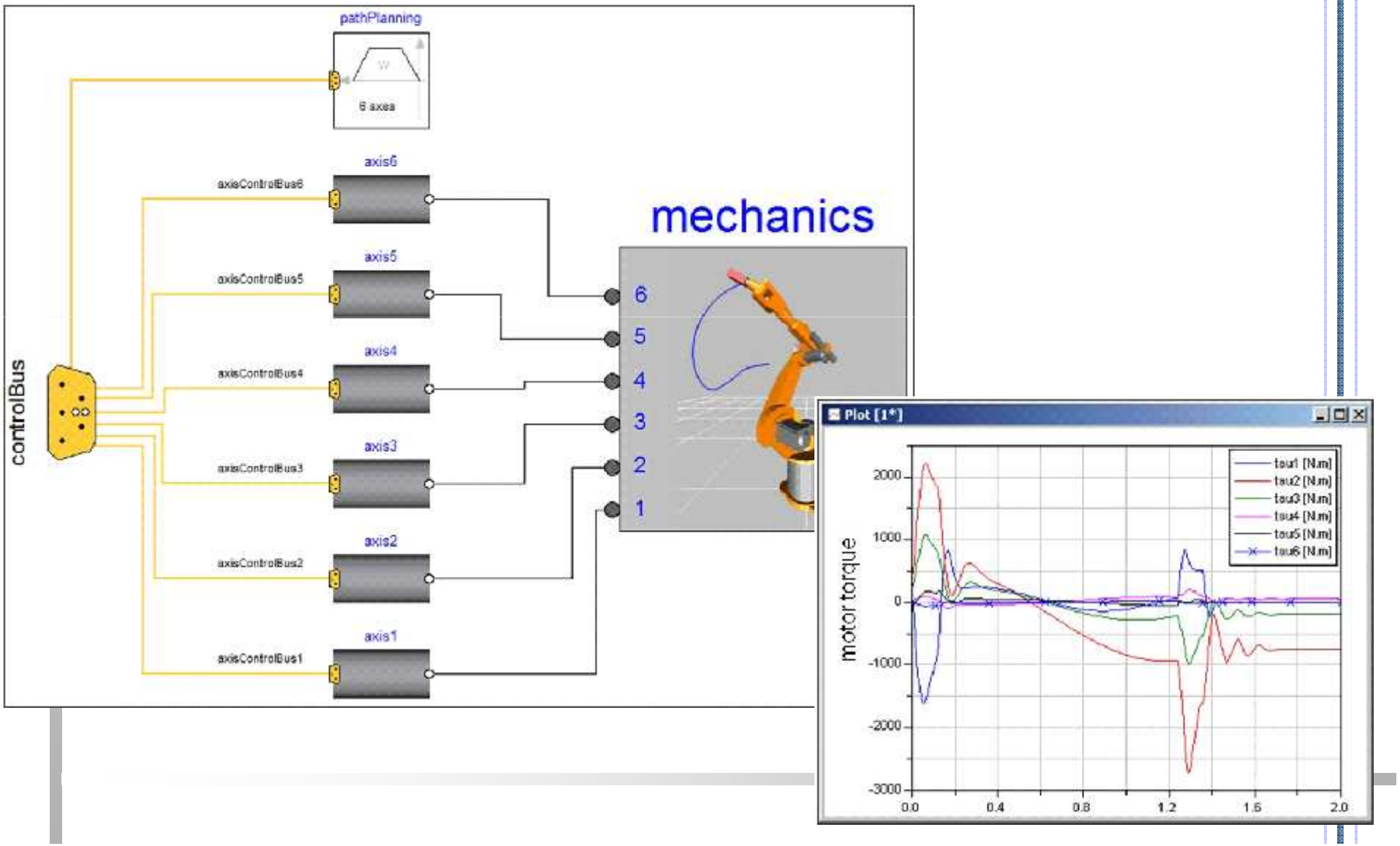
SysML4Modelica Analytical Model: Alloca

火龙果•整理
uml.org.cn



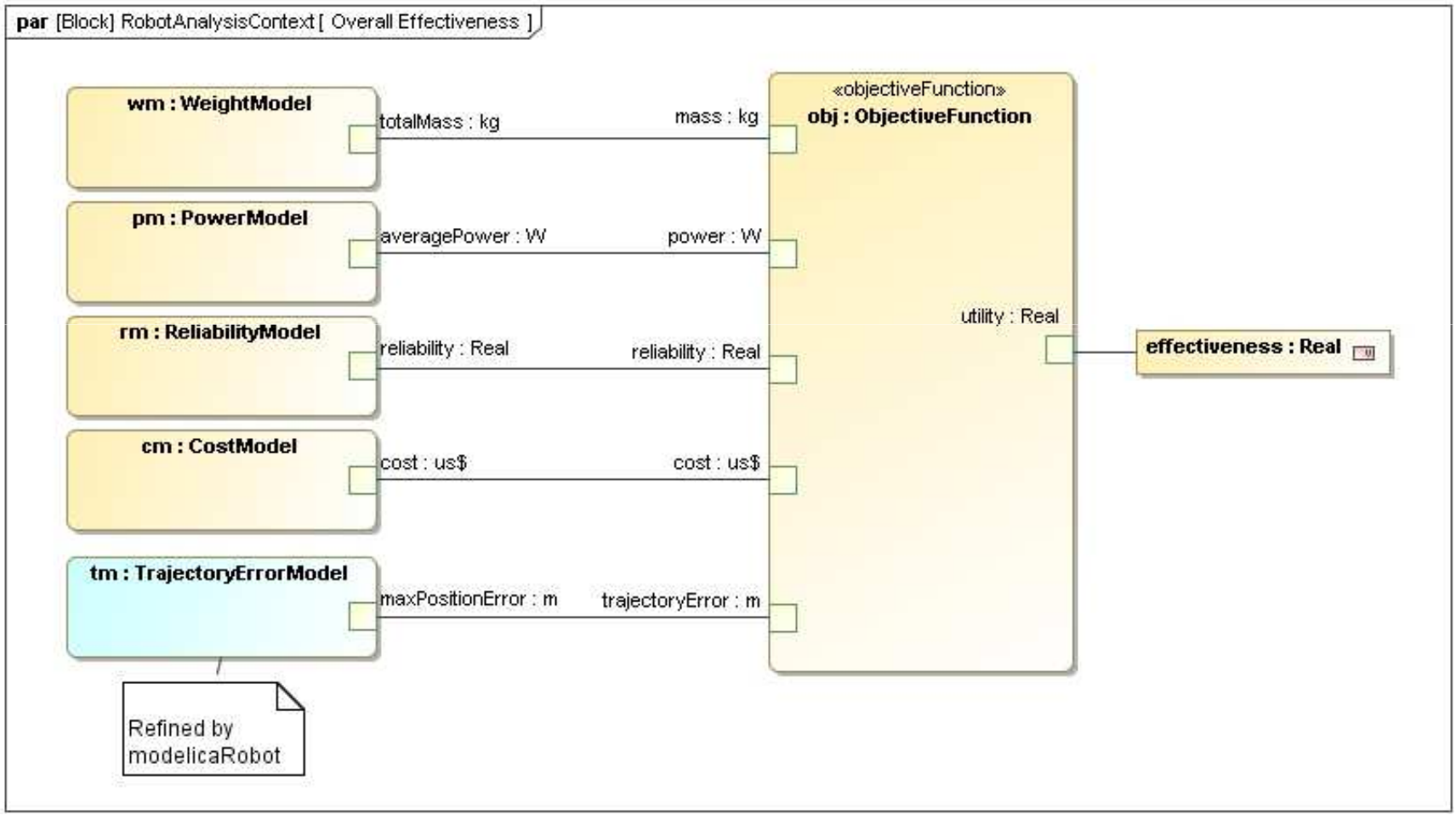
SysML-Modelica Robot Example: Modelica model with simulation results

火龙果•整理
uml.org.cn



SysML-Modelica Robot Example: Analysis and Trade Study

火龙果•整理
uml.org.cn



Analysis results are incorporated in Trade Study

Presentation Overview

火龙果•整理
uml.org.cn

- What is SysML?
- What is Modelica?

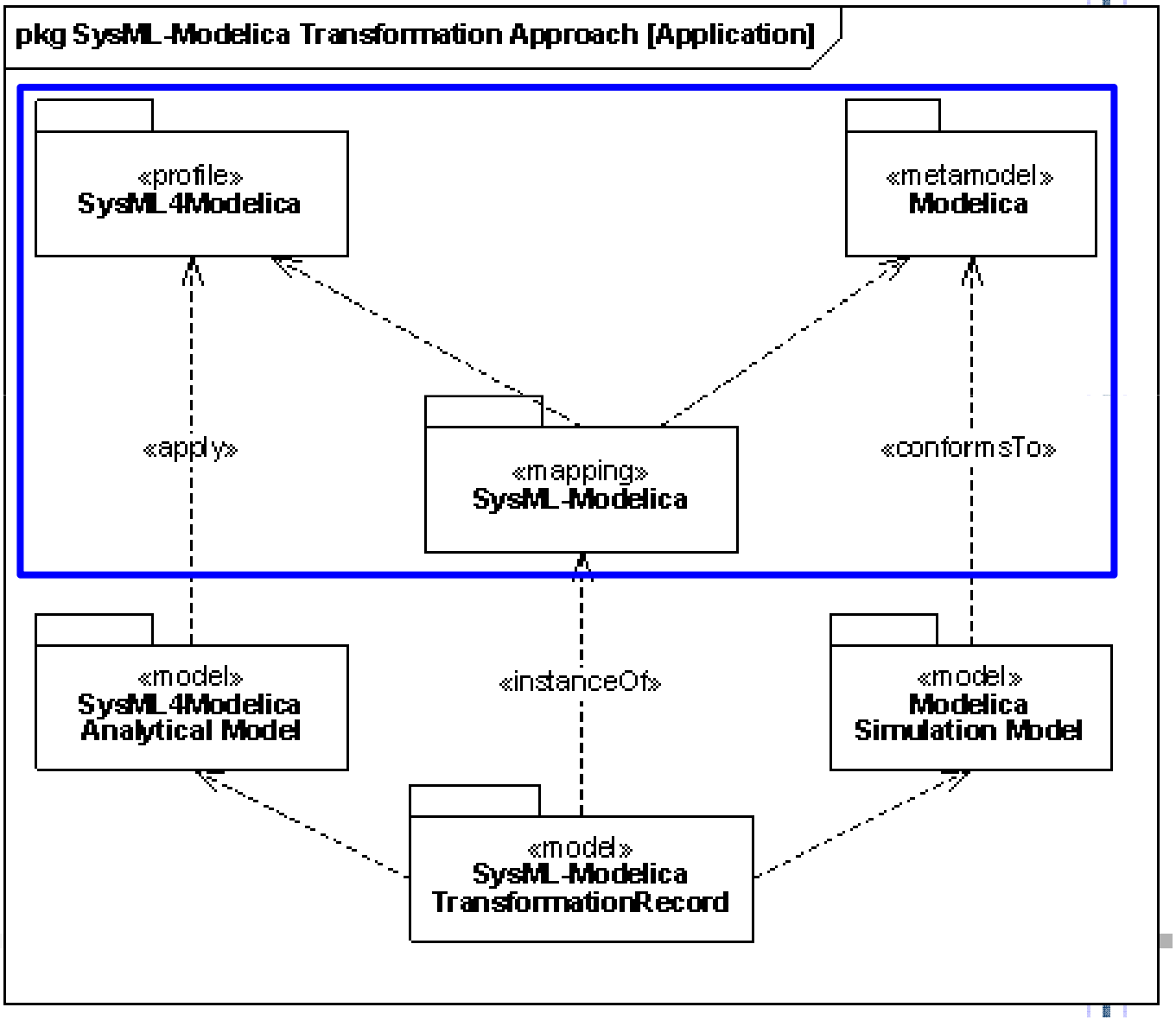
- Motivating Example: Design & Analysis of Robot

- SysML-Modelica Transformation Specification
- Transformations in Systems Modeling
- Timeline towards Specification Adoption
- Summary

SysML-Modelica Transformation Specification

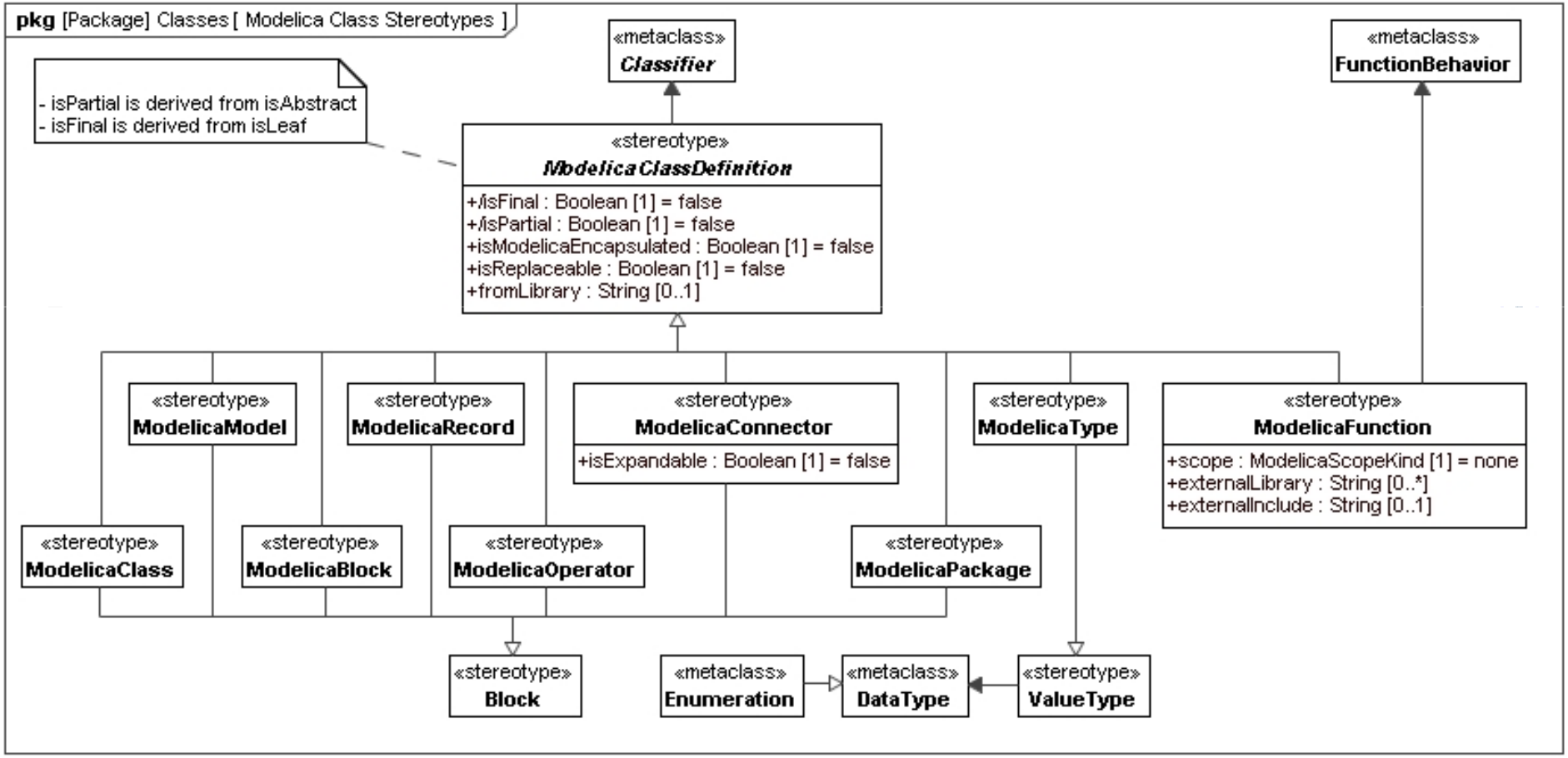
火龙果•整理
uml.org.cn

SysML-Modelica Transformation follows the principles of Model-Driven Architecture (MDA)



SysML4Modelica Profile

火龙果•整理
uml.org.cn

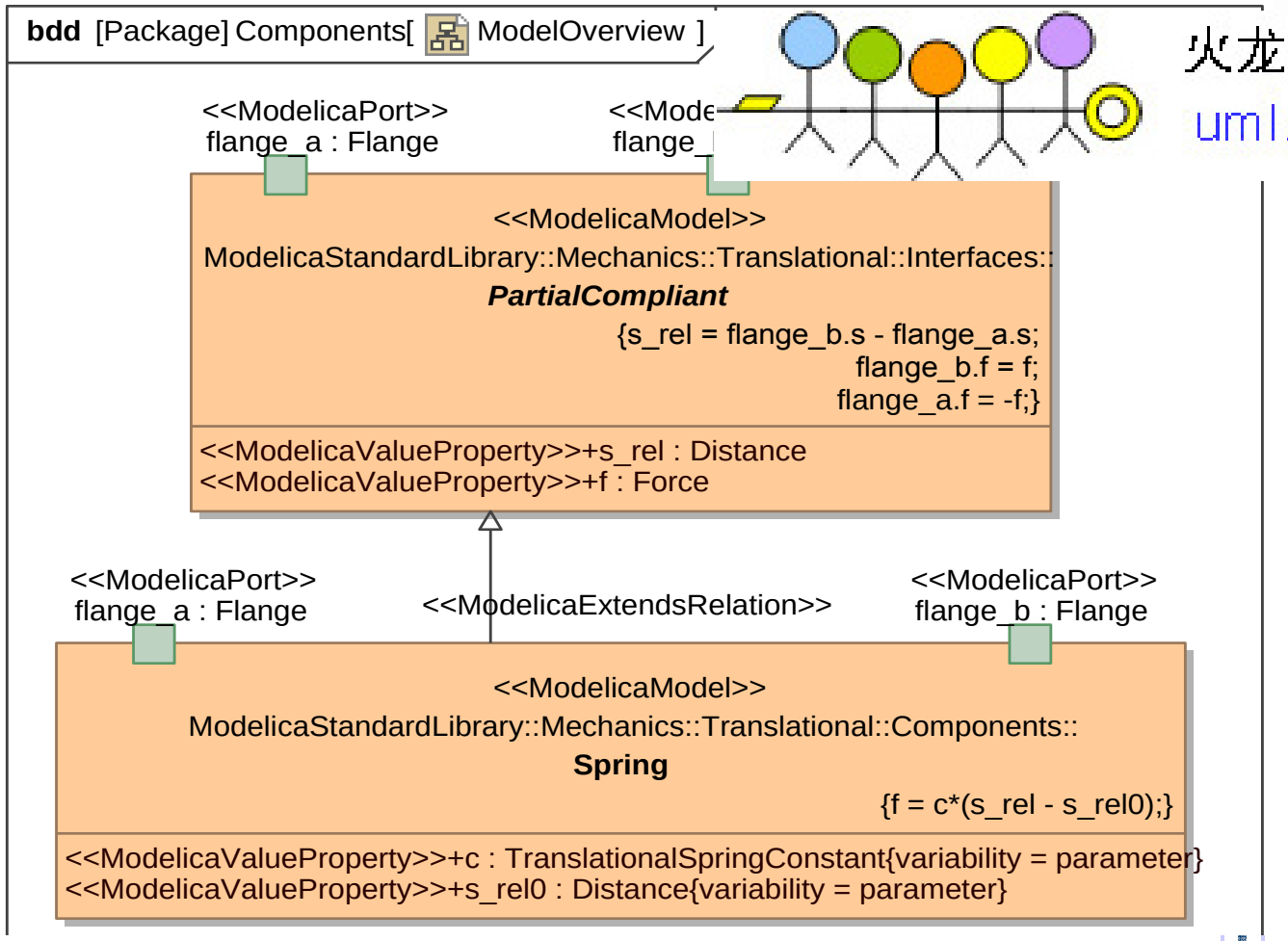


火龙果•整理
uml.org.cn

SysML4Modelica

Formal mapping

Modelica

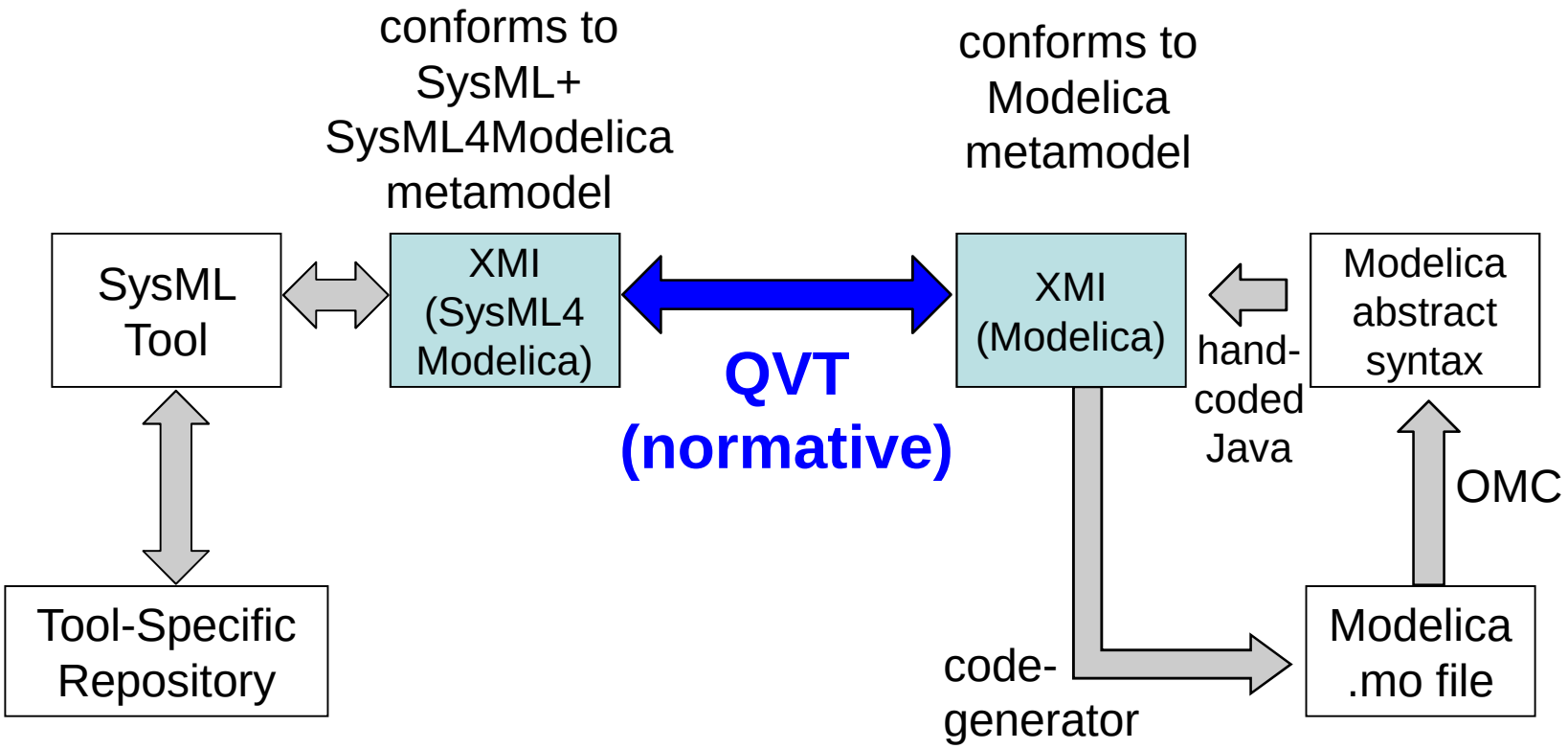



```
model Spring "Linear 1D translational spring"
  extends Translational.Interfaces.PartialCompliant;
  parameter SI.TranslationalSpringConstant c(final min=0, start = 1)
    "spring constant ";
  parameter SI.Distance s_rel0=0 "unstretched spring length";

equation
  f = c*(s_rel - s_rel0);
end Spring;
```

Reference implementation: Based on OMG QVT

火龙果•整理
uml.org.cn

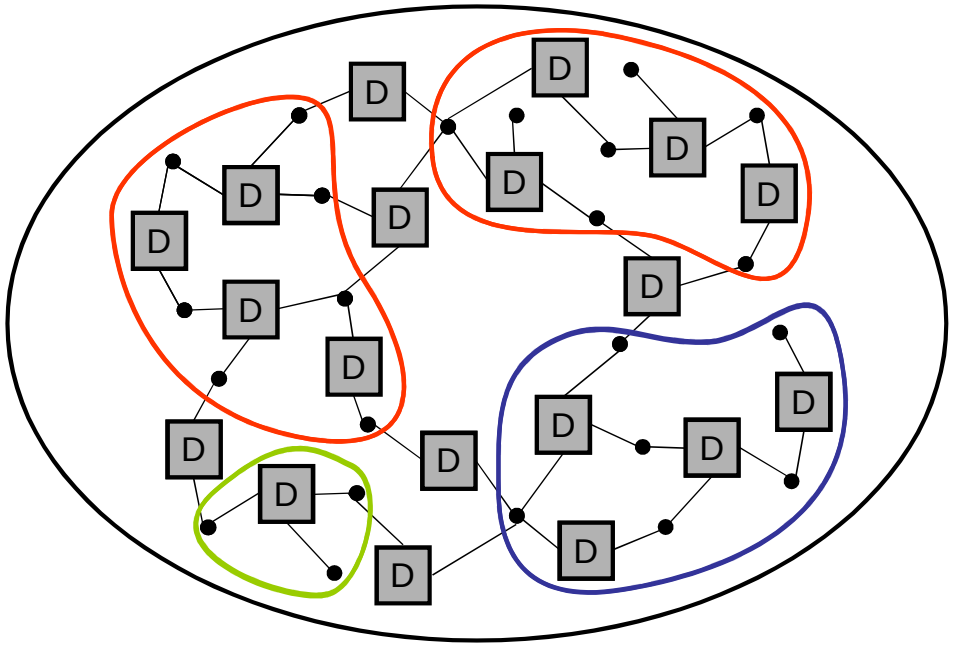


QVT = Query / View / Transformation

Transformations in Systems Modeling

火龙果•整理
uml.org.cn

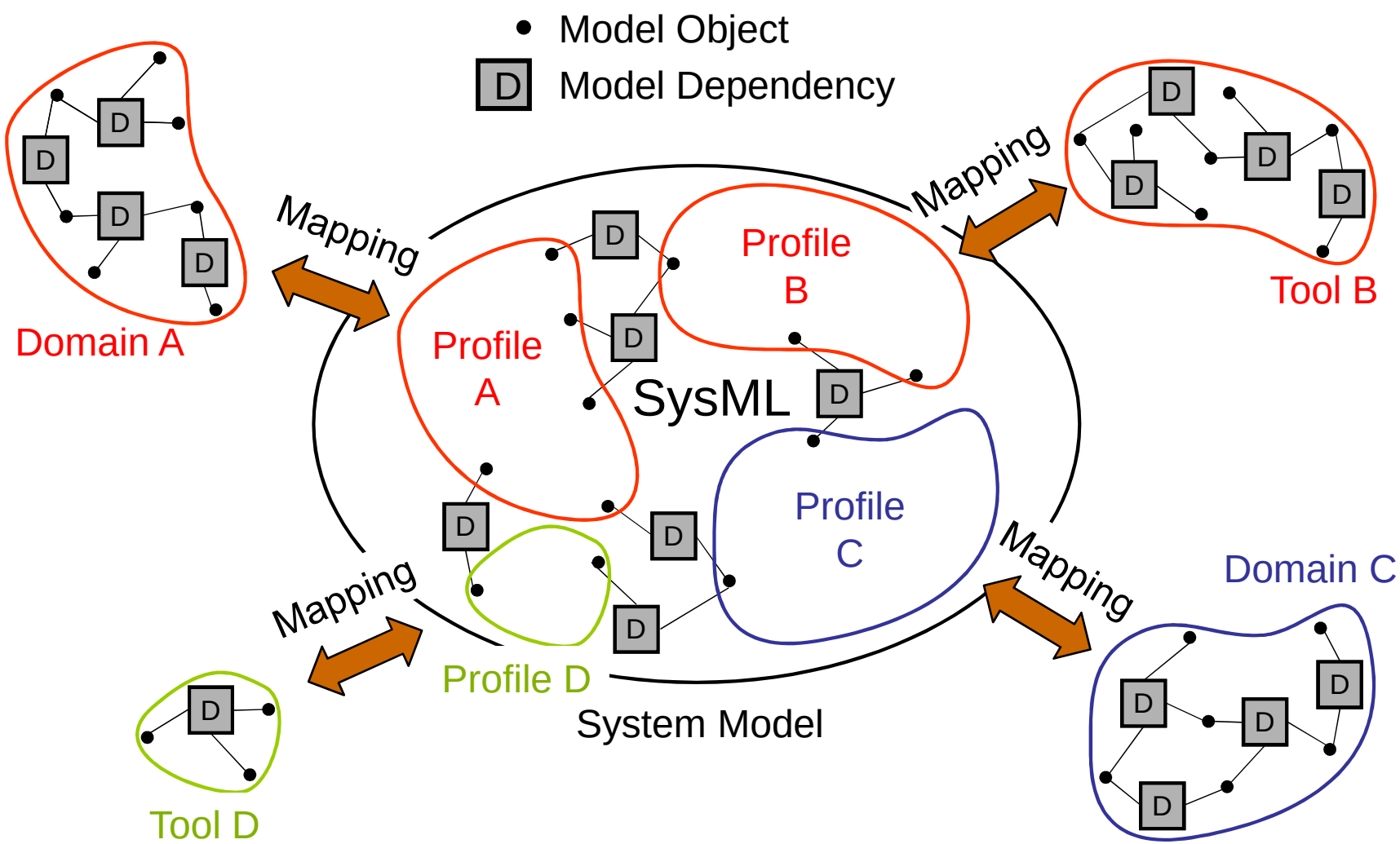
- Model Object
- D Model Dependency



System Model

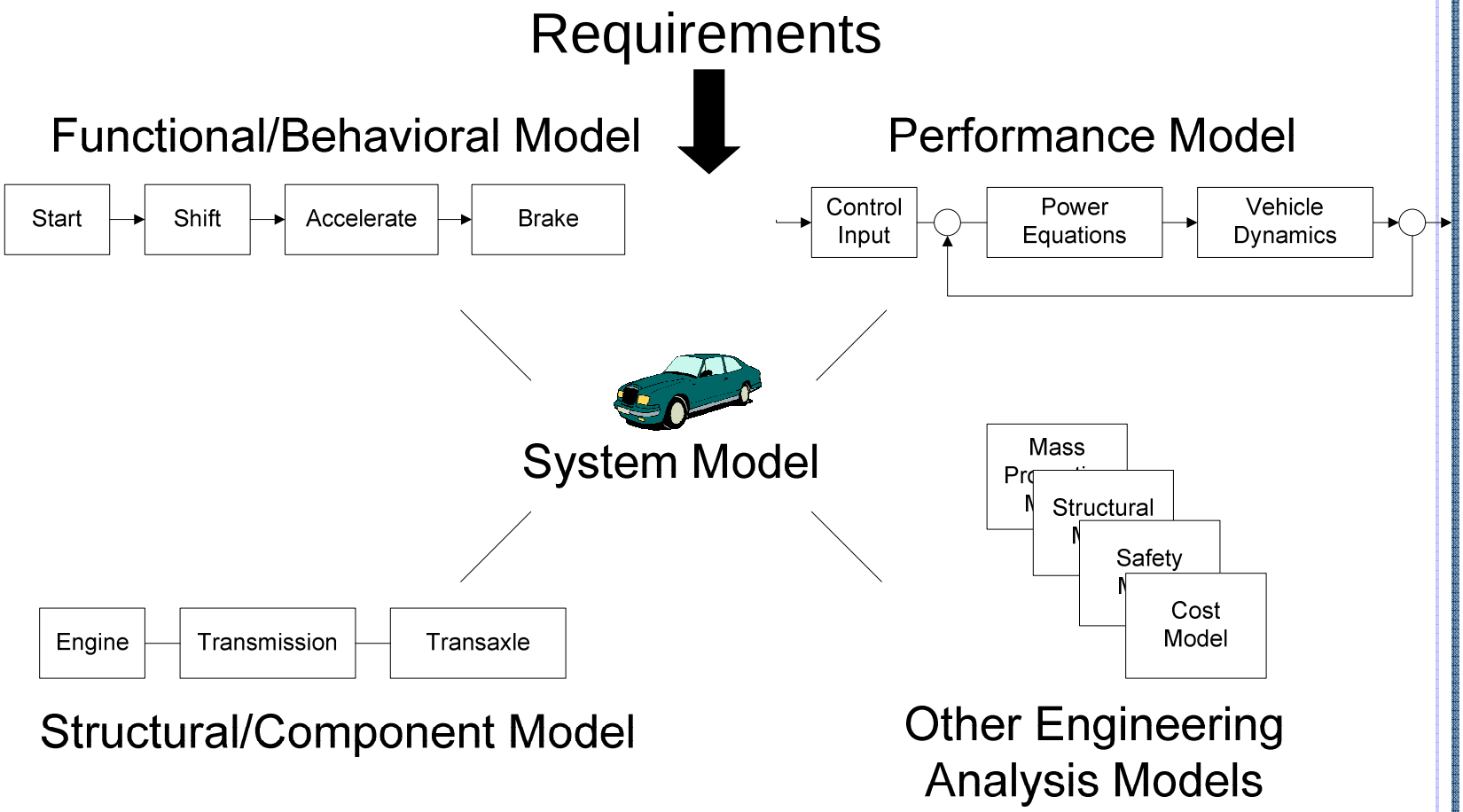
Transformations in Systems Modeling

火龙果•整理
uml.org.cn



Model Reuse in MBSE

火龙果•整理
uml.org.cn



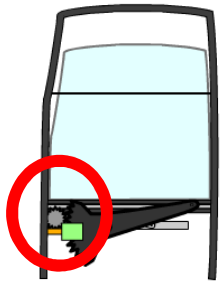
Creating Models is Expensive and Time-Consuming

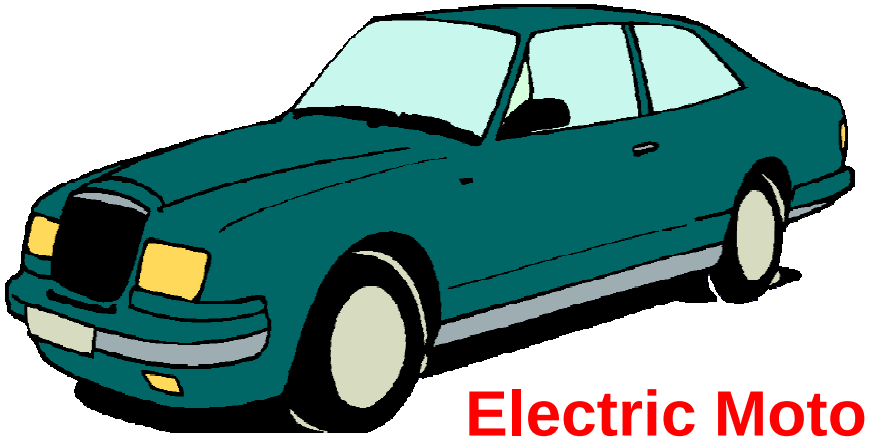
Revision by GIT; Original Source: OMG SysML Tutorial (June 2008). Reprinted with permission. Copyright © 2006-2008 by Object Management Group.

Reusable Models in MBSE

火龙果•整理
uml.org.cn

- Physical components are reused
- Portions of the systems model repeat
- Patterns for instantiating these portions





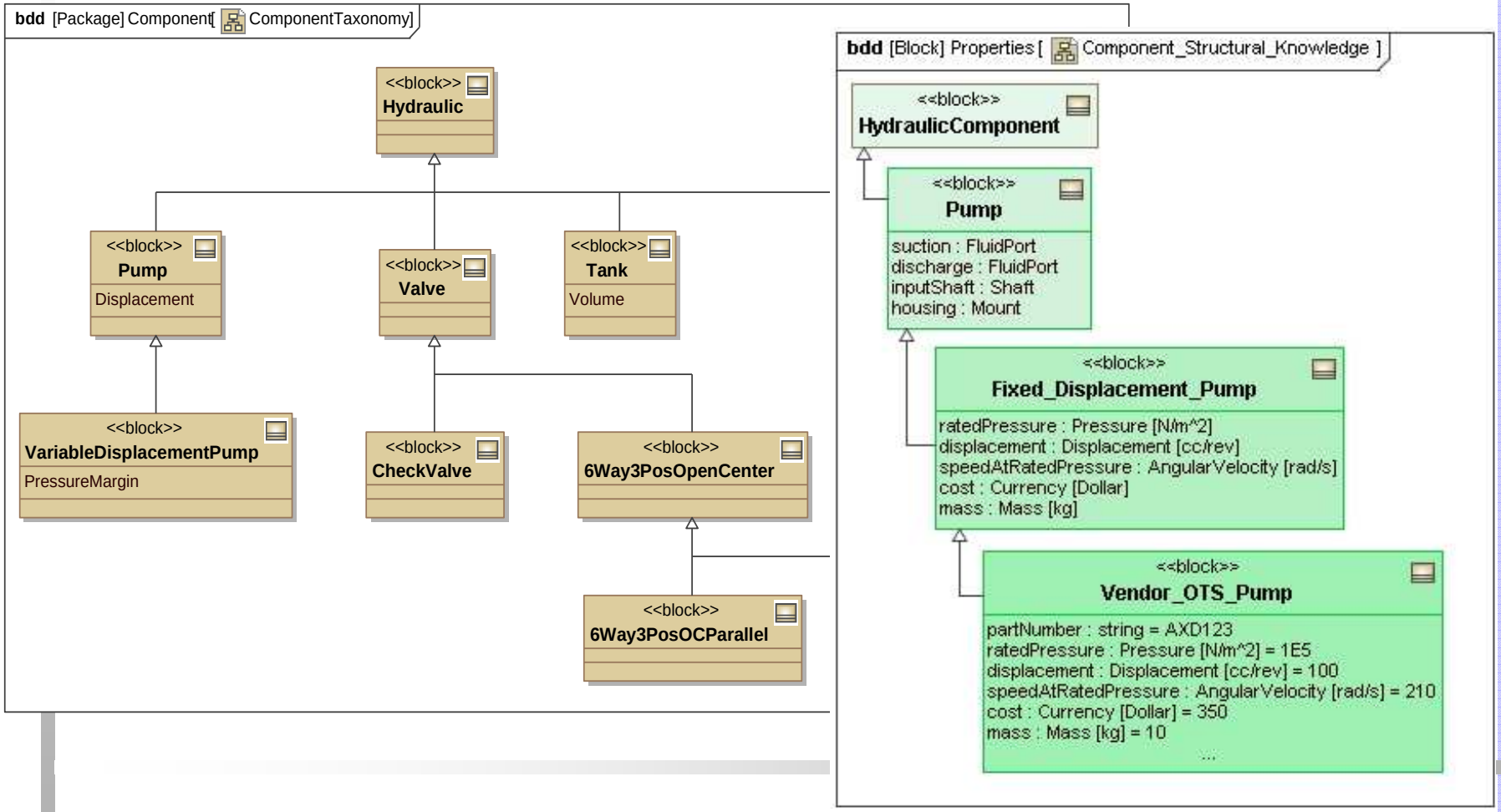
Electric Motors

- Component models → Domain specific model libraries
- Application of pattern = model transformations

Model Library of Hydraulic Component

火龙果•整理
uml.org.cn

- Needs to be carefully designed and managed
- Encodes domain knowledge

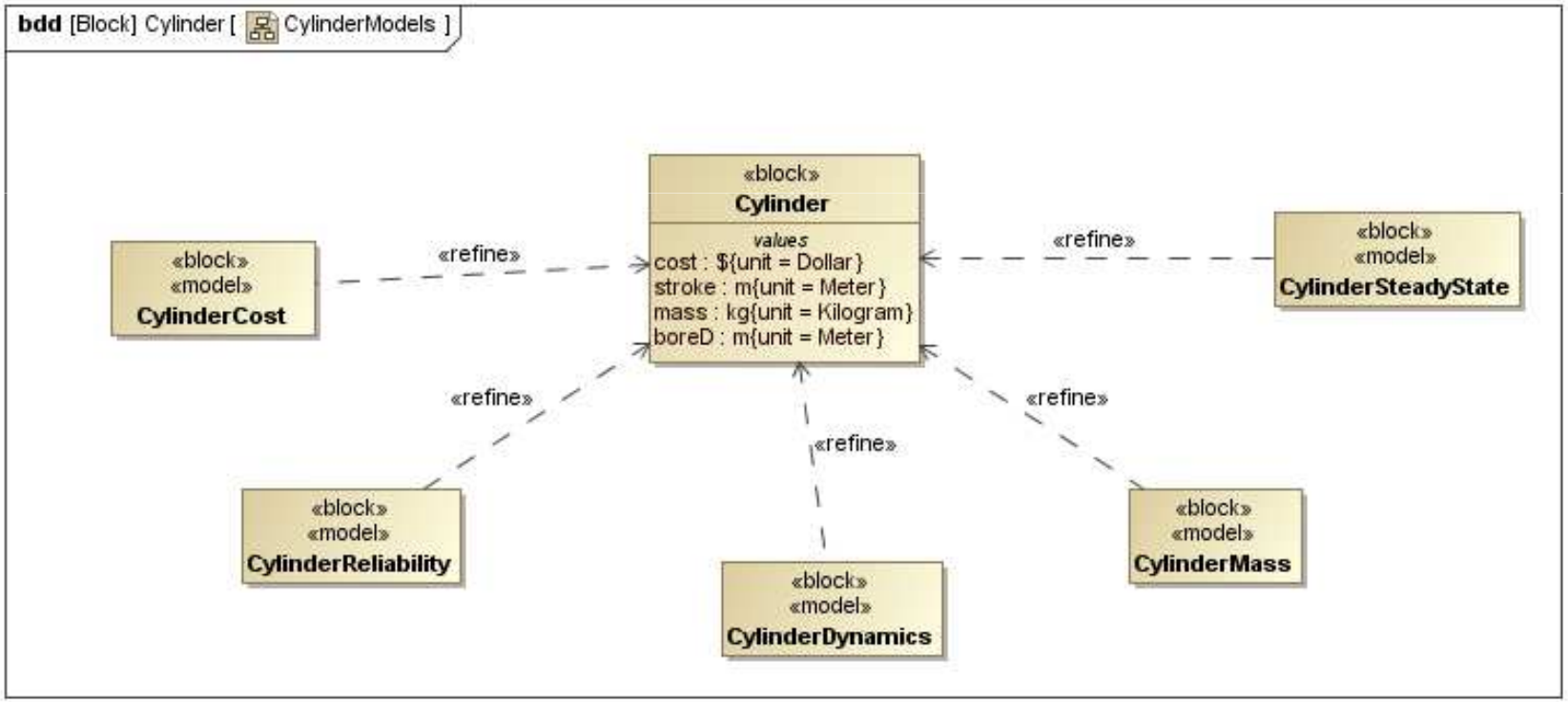


Other Perspectives of Cylinder are Reusable

火龙果•整理
uml.org.cn

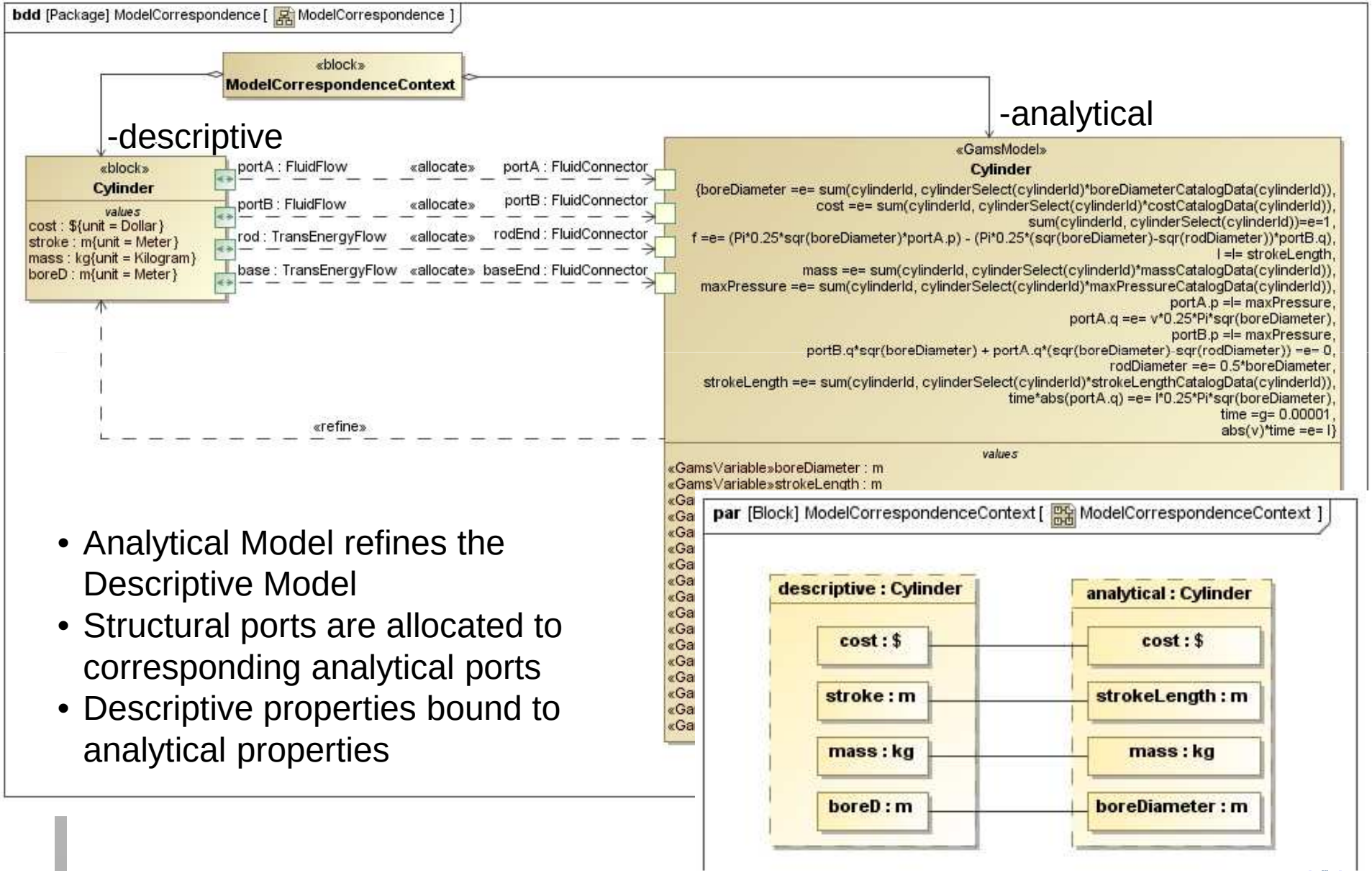
- When cylinder is used, other corresponding models are often used also

→ Capture the reuse pattern



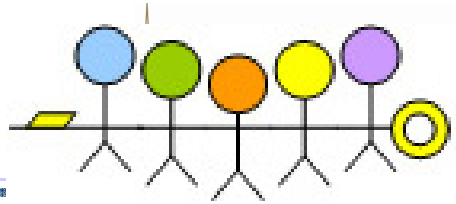
Correspondence Patterns

火龙果•整理
uml.org.cn

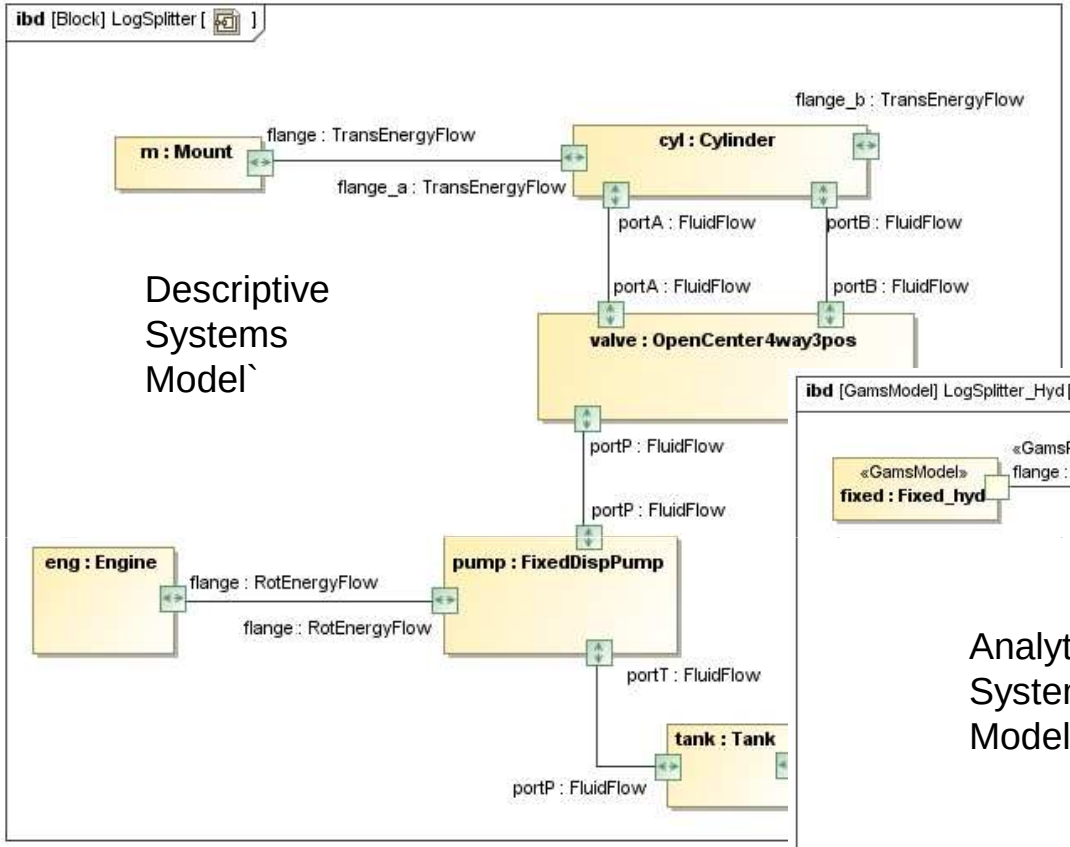


- Analytical Model refines the Descriptive Model
- Structural ports are allocated to corresponding analytical ports
- Descriptive properties bound to analytical properties

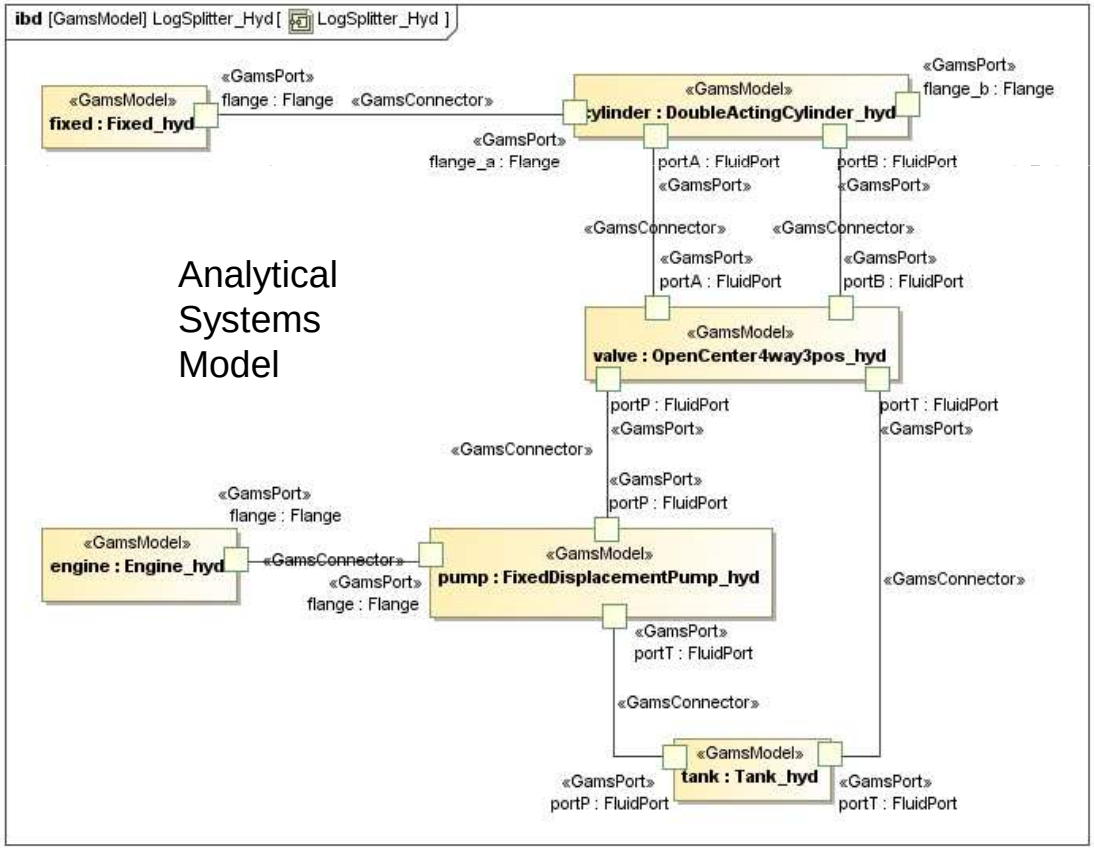
Model Composition using Model Transformations



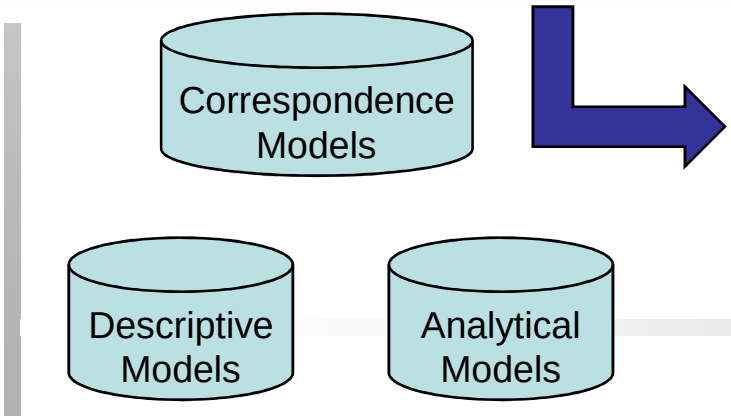
火龙果•整理
uml.org.cn



Descriptive Systems Model`

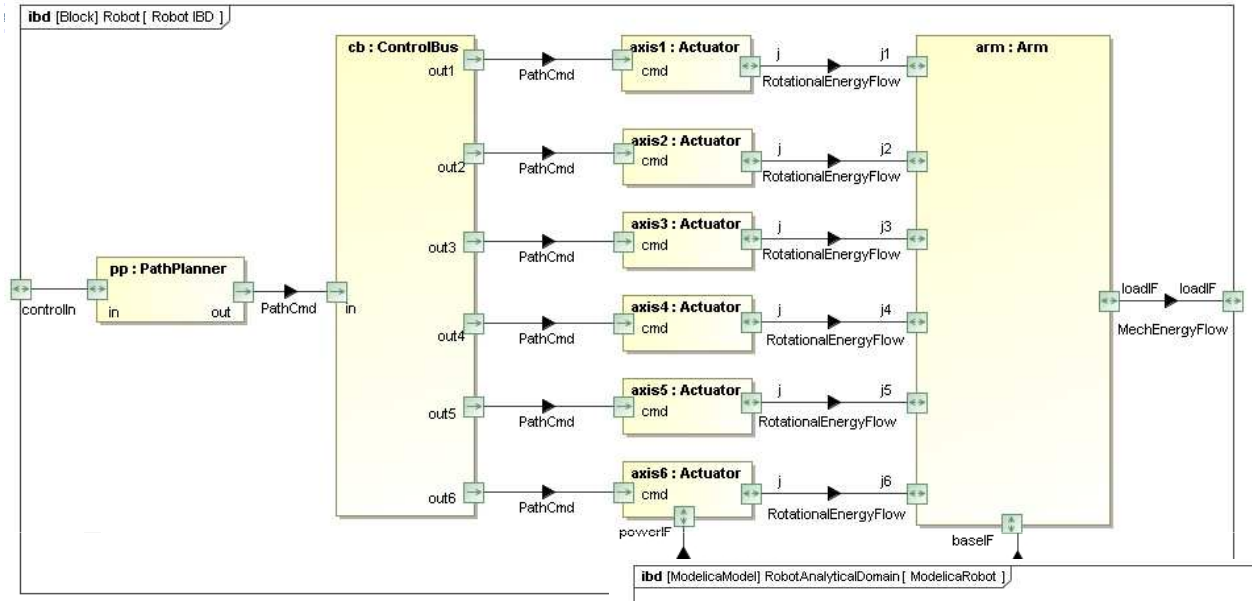


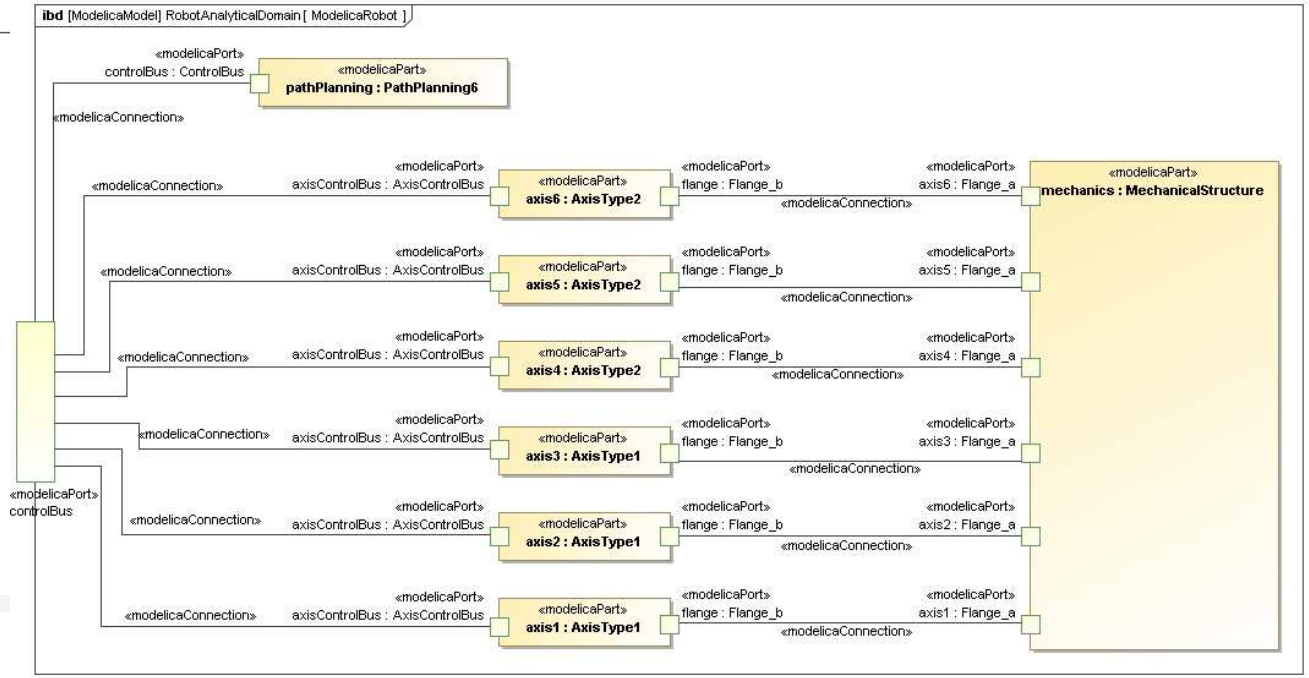
Analytical Systems Model

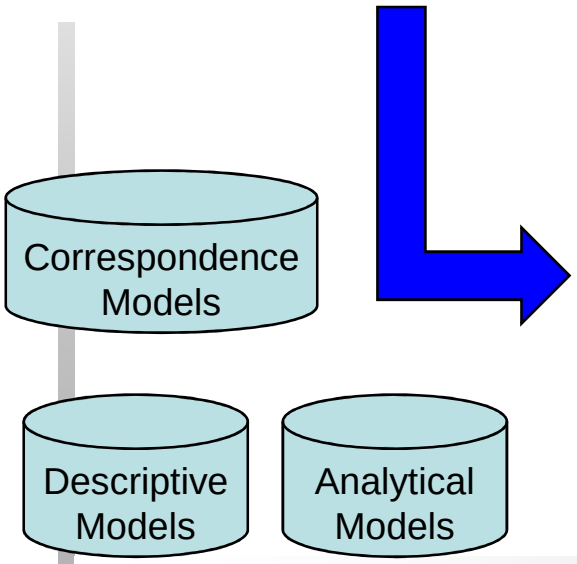


Descriptive to Analytical Transformatio

火龙果•整理
uml.org.cn







Summary

火龙果•整理
uml.org.cn

- Objective:
  - Leverage the strengths of both SysML and Modelica by integrating them to create a more expressive and formal MBSE language.

Descriptive Modeling in SysML

+

Formal Equation-Based Modeling for Analyses and Trade Studies in Modelica

http://doc.omg.org/syseng/2010-6-8

Acknowledgements

火龙果•整理
uml.org.cn

Working Group Members

- Yves Bernard (EADS)
- Roger Burkhart (Deere & Co)
- Wuzhu Chen (Univ. Braunschweig)
- Hans-Peter De Koning (ESA)
- Sandy Friedenthal (Lockheed Martin)
- Peter Fritzson (Linköping University)
- Nerijus Jankevicius (No Magic)
- Alek Kerzhner (Georgia Tech)
- Andreas Korff (Atego)
- Chris Paredis (Georgia Tech)
- Axel Reichwein (Georgia Tech)
- Nicolas Rouquette (JPL)
- Wladimir Schamai (EADS)

Students / post-docs

- Kevin Davies
- Sebastian Herzig
- Alek Kerzhner
- Ben Lee
- Roxanne Moore
- Marc Pare
- Axel Reichwein
- Wladimir Schamai

Sponsors

- Deere & Co
- Lockheed Martin
- National Science Foundation

http://doc.omg.org/syseng/2010-6-8