Component-based Modeling of Dynamic Systems using Heterogeneous Composition

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Motivation

(i) the composition includes causal and acausal components,
(ii) physical variables are shared across component boundaries,
(iii) component behavior models are represented using different paradigms (Bond Graphs, Modelica)
(iv) the models are supplied by different tools.

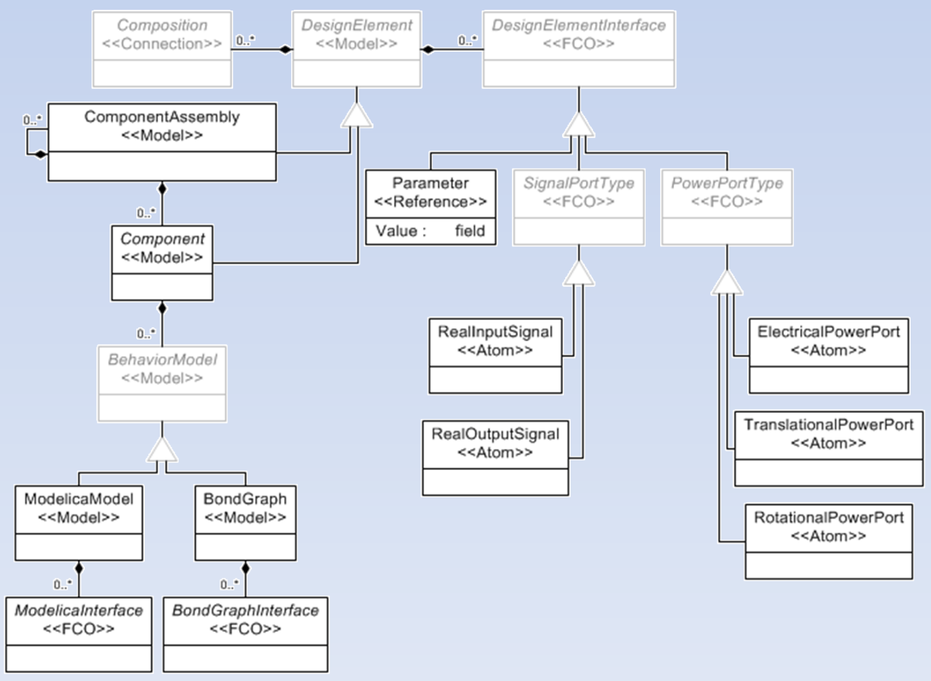
Cyber-Physical Modeling Language (CyPhyML)

A **Component** in CyPhyML is an atomic building block. A CyPhyML component is defined by its interfaces:

(i) Parameters (causal),
(ii) signal ports (causal)
(iii) power ports (acausal, equation based).

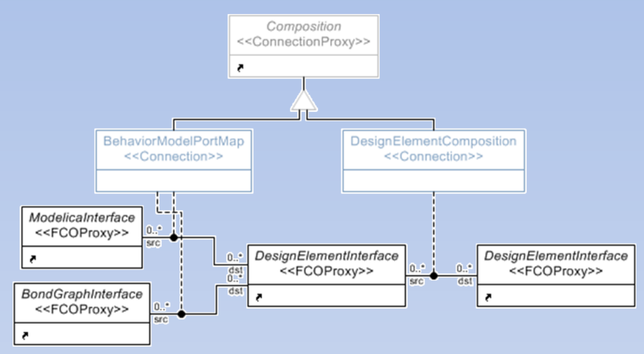
Component Assemblies have the same interfaces as components. There are two key differences between components and component assemblies:

(i) Component assemblies can contain other components and other component assemblies;
(ii) behavior of component assemblies is defined implicitly through the composition of its child objects, but behavior of components is defined explicitly in its behavior model.



Composition in CyPhyML

(i) Mapping between behavioral model and component level interfaces
(ii) Composition between CyPhyML components and Component Assemblies



Modelica

Electrical

$$A.voltage = B.voltage$$
$$A.current + B.current = 0$$

$$ModelicaModel.p.v = positive.voltage$$
$$ModelicaModel.p.i + positive.current = 0$$

Rotational

$$A.angle = B.angle$$
$$A.torque + B.torque = 0$$

Translational

$$A.position = B.position$$
$$A.force + B.force = 0$$

Bond Graph

Electrical

$$A.effort = B.voltage$$
$$A.flow + B.current = 0$$

$$BondGraph.positive.effort = positive.voltage$$
$$BondGraph.positive.flow + positive.current = 0$$

Rotational

$$A.flow = der(B.angle)$$
$$A.effort + B.torque = 0$$

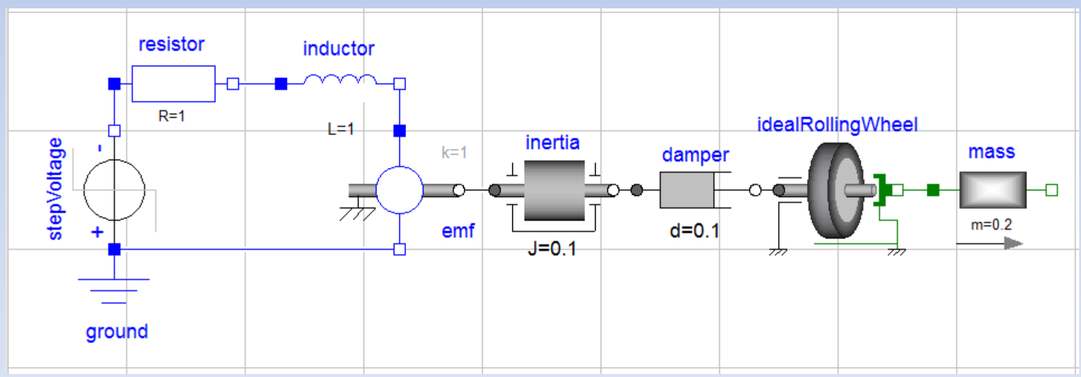
Translational

$$A.flow = der(B.position)$$
$$A.effort + B.force = 0$$

Schematic diagram of a simple example

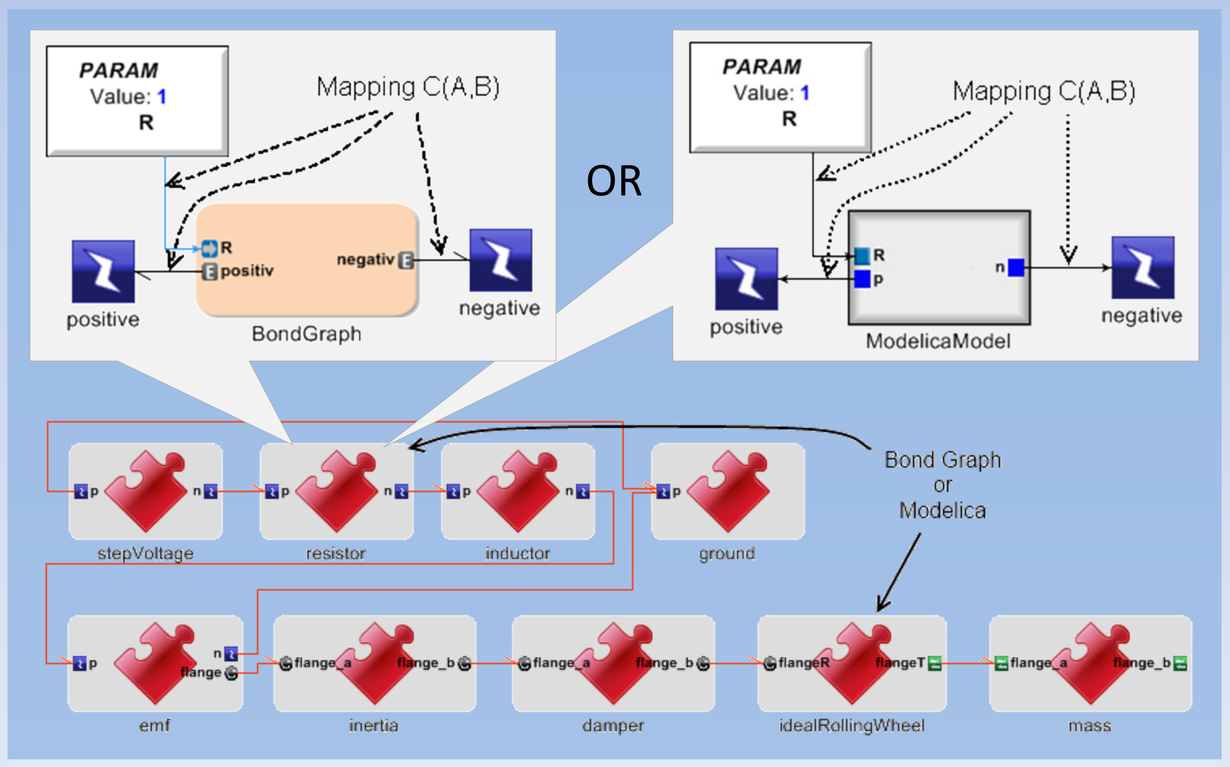
Three different physical domain

(i) electrical (*stepVoltage*, *resistor*, *inductor* and *emf*),
(ii) mechanical rotational (*emf*, *inertia*, *damper* and *idealRollingWheel*)
(iii) mechanical translational (*idealRollingWheel* and *mass*).



CyPhyML diagram of the simple example

(i) a common, consistent modeling framework that can interface to models that are based on various formalisms and paradigms,
(ii) a composition approach that is able to integrate and simulate the system as a whole,
(iii) the ability to adapt the system models to widely used tools in order to able to simulate the composed system.



Simulation results

CyPhyML to Modelica transformation makes composed Modelica model generation possible. The generated Modelica code can be executed using Modelica tool. The simulation results are identical even we changed some Modelica components to Bond Graphs. The plot shows the simulation results (of one case) of:

(1) the angular velocity of the *inertia*,
(2) the force on the translational interface of the *idealRollingWheel*,
(3) the current on the positive electrical pin of the *resistor*.