2nd Annual OpenModelica Workshop Feb 8, 2010

Workshop Opening

OpenModelica – Status and Directions

Peter Fritzson

To All Participants!

Very Welcome to this Second Annual OpenModelica Workshop!

New OpenModelica Web Site from February 2010
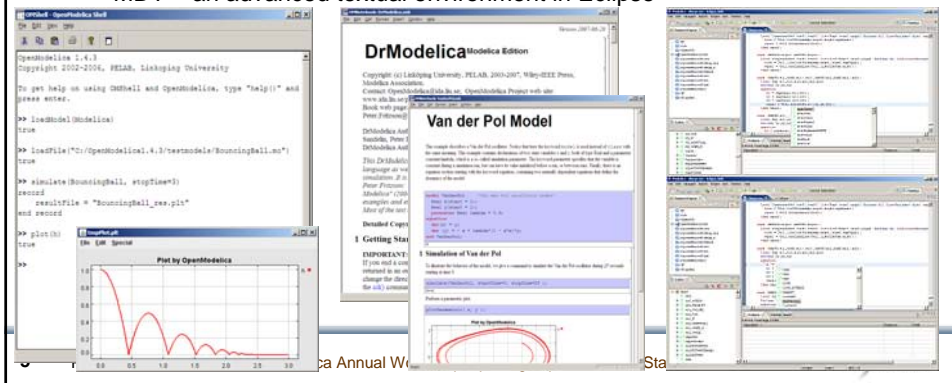

Goals for the OpenModelica Effort

- Comprehensive modeling, simulation and systems engineering environment for research, teaching, and industrial usage

- Open-source for both academic and commercial usage

- Invitation for open-source cooperation around OpenModelica, tools, and applications

Current OpenModelica   www.openmodelica.org

- Advanced Interactive Modelica compiler (OMC)
  - Supports most of the Modelica Language
- Basic environment for creating models
  - OMShell – an interactive command handler   * ModelicaML UML Profile
  - OMNotebook – a literate programming notebook * MetaModelica transforms
  - MDT – an advanced textual environment in Eclipse

Expanded Vision for OpenModelica Effort: Integrated Model-driven Development
Based on OpenModelica, e.g. in OPENPROD project
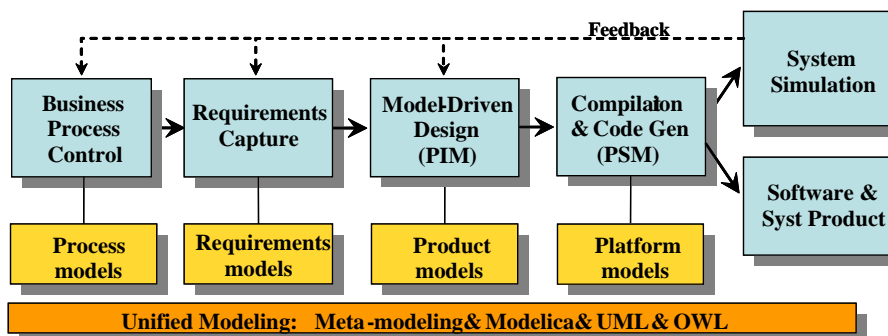
Vision of unified modeling framework for model-driven product development from platform independent models (PIM) to platform specific models (PSM)

The Open Source Modelica Consortium

Purpose of the Consortium

- The Open Source Modelica Consortium, created the 4th of December 2007 in Linköping, Sweden, in the following called OSMC, is a non-profit, non-governmental organization with the aim of developing and promoting the development and usage of the **OpenModelica open source implementation of the Modelica computer language** (also named Modelica modeling language) and OpenModelica **associated open-source tools and libraries**, collectively named the OpenModelica Environment, in the following referred to as OpenModelica.

- OpenModelica is **available for commercial and non-commercial usage under the conditions of the OSMC Public License**. It is the aim of OSMC, within the limitations of its available resources, to provide **support and maintenance of OpenModelica**, to support its publication on the web, and to **coordinate** contributions to OpenModelica.

Open Source Modelica Consortium Originally Created Dec 4, 2007

7 Founding Organizational Members

- Bosch-Rexroth AG, Germany
- Equa Simulation AB, Sweden
- TLK Thermo, Germany
- VTT, Finland
- Linköping University, Sweden
- Hamburg University of Technology/TuTech, Institute of Thermo-Fluid Dynamics, Germany
- Technical University of Braunschweig, the Institut of Thermodynamik, Germany

31 Dec 2008: Open Source Modelica Consortium – Expanded to 19 Organizational Members

Companies and Institutes (11 members)

- Bosch-Rexroth AG, Germany
- Equa Simulation AB, Sweden
- TLK Thermo, Germany
- VTT, Finland
- MostforWater, Belgium
- MapleSoft, Canada
- Emmeskay Inc., USA
- IFP, Paris, France
- Siemens Turbo Machinery AB
- ABB Corporate Research
- MathCore Engineering AB

Universities (8 members)

- Linköping University, Sweden
- Hamburg University of Technology/TuTech, Institute of Thermo-Fluid Dynamics, Germany
- Technical University of Braunschweig, the Institut of Thermodynamik, Germany
- Université Laval, the modelEAU group, Canada
- Griffith University, Australia
- University of Queensland, Australia
- Politecnico di Milano, Italy
- Mälardalen University, Sweden

Now: OSMC – Expanded to 28 Organizational Members, 31 Dec, 2009 (29 members today...)

Companies and Institutes (16 members)
- ABB Corporate Research, Sweden
- Bosch Rexroth AG, Germany
- Siemens Turbo Machinery AB, Sweden
- CDAC Centre for Advanced Computing, Kerala, India
- Creative Connections, Prague, Czech Republic
- Frontway AB, Sweden
- Equa Simulation AB, Sweden
- IFP, Paris, France
- InterCAX, Atlanta, USA
- MOSTforWATER, Belgium
- MathCore Engineering AB, Sweden
- Maplesoft, Canada
- TLK Thermo, Germany
- VI-grade, Italy
- VTT, Finland
- XRG Simulation, Germany

Universities (13 members)
- Linköping University, Sweden
- Hamburg University of Technology/TuTech, Institute of Thermo-Fluid Dynamics, Germany
- FH Bielefeld, Bielefeld, Germany
- Technical University of Braunschweig, Institute of Thermodynamics, Germany
- Technical University of Dortmund, Process Dynamics and Operations Group, Germany
- Université Laval, modelEAU group, Canada
- Griffith University, Australia
- University of Queensland, Australia
- Politecnico di Milano, Italy
- Mälardalen University, Sweden
- Technical University Dresden, Germany
- Telemark University College, Norway
- Ghent University, Belgium

Open Source Modelica Consortium Individual Members

(43 individual members, 8 February 2010)

- Peter Fritzson Adrian Pop, David Akhvlediani, Bernhard Bachmann, Vasile Baluta, Simon Björklén, Mikael Blom, Willi Braun, David Broman, Stefan Brus, Francesco Casella, Filippo Donida, Henrik Eriksson, Anders Fernström, Jens Frenkel, Pavel Grozman, Daniel Hedberg, Michael Hanke, Alf Isaksson, Kim Jansson, Daniel Kanth, Tommi Karhela, Joel Klinghed, Juha Kortelainen, Alexey Lebedev, Magnus Leksell, Oliver Lenord, Håkan Lundvall, Henrik Magnusson, Eric Meyers, Hannu Niemistö, Kristoffer Norling, Atanas Pavlov, Pavol Privitzer, Per Sahlin, Wladimir Schamai, Gerhard Schmitz, Klas Sjöholm, Martin Sjölund, Kristian Stavåker, Mohsen Torabzadeh-Tari, Niklas Worschech, Robert Wotzlaw

OSMC Work on OpenModelica During Past Year 2009

- Focus on OpenModelica compiler frontend improvements to support the Modelica Standard Libraries MultiBody and Media/Fluid.
- Technical difficulties and work estimates too low by a factor 2-3. Work force expanded from 1 to 3-4 full-time developers from Dec 2009. Rate of progress increased.
- The comment-preserving unparser/refactoring functionality was complete to 80% level (functionality works, some performance improvements still needed)
- The new solver interface completed but still needs to be fully integrated.
- Draft OpenModelica Text template language for producing code generators. Used to develop next generation C and C# code generators from OpenModelica.

Special Thanks To:

- The developers (Especially Adrian) who worked very hard during 2009. Adrian Pop, Martin Sjölund, Per Östlund, Hannu Niemistö, Alexey Lebedev, and many others.
- The 28 OpenModelica consortium org members for support, especially Bosch-Rexroth, with OSMC Chairman Oliver Lenord; ABB, Siemens, etc...
- MathCore Engineering AB for contributing 1 many-year of source code and supporting the development during 2009 (Aronsson et al)
- Master students and PhD students who made important contributions.

Outlook for 2010

- February 2010. Change to standard GPL v3 open source license option instead of OSMC-GPL license option.
- Spring 2010. Continued **high priority** on OpenModelica compiler frontend for better support for the Modelica standard **libraries**.
  - **Completion of MultiBody library and Fluid/Media library flattening support.**
- Spring 2010. Support for interactive simulation.
- During 2010. **Improved scalability** – support for larger models and improved simulation efficiency. Further improved library support.
- During 2010. Support for full Modelica 3.1 and certain Modelica 3.2 features.
- During 2010. Better support for simulation, e.g. better event handling, simple tearing support.

Outlook for 2010, Cont'

- Fall 2010. Modelica debugger, partly based on existing MetaModelica debugger.
- Complete the work on compiler enhancements for bootstrapping the compiler (gives better programmability for the OMC developer, e.g. for-loops, while-loops, etc. available together with MetaModelica, and avoids maintenance of two compilers)
- Restructuring the code generator for easier supporting different code generation variants, based on the new OpenModelica text template language.

- Also: research on multi-core parallel code generation
- Also: research on SysML-Modelica integration
- Also: research on type systems and semantics
- ...

Open Source Modelica Consortium – OSMC Board of Directors

- **Oliver Lenord**, OSMC Chairman; Manager, Bosch-Rexroth, Germany
- **Per Sahlin**, OSMC Vice Chairman; CEO, Equa Simulation AB,
- **Peter Fritzson**, OSMC Director; Prof, Linköping University, Sweden
- **Juha Kortelainen**, Manager, VTT, Finland
- **Gerhard Schmitz**, Prof, Univ. Hamburg, Germany
- **Alf Isaksson**, Manager, ABB Corp. Research, Sweden
- **Francesco Casella**, Prof, Politecnico di Milano, Italy
- **Jan Brugård**, CEO, MathCore Engineering AB, Sweden)

OSMC Board – 8 Meetings Jan 1 2009 – Dec 31 2009

Meeting dates
- 090120
- 090331
- 090506
- 090629
- 090902
- 091002
- 091109
- 091215

Board Work
- Planning and prioritizing the OSMC work
- Admitting new members
- Planning the workshop
- Budget
- etc.

OPENPROD –OpenModelica related Project

- Duration: June 2009 – Sept 2012 (3.3 years)
- Budget: approx 11 Meuro, 94 Manyears
- 28 partners
- Very important for future OpenModelica development

Main workpackages
- Integrated hardware software modeling by Modelica - UML - SysML integration.
- Model compiler enhancements.
- Compilation of Modelica to parallel multi-core platforms.
- Tool interoperability.
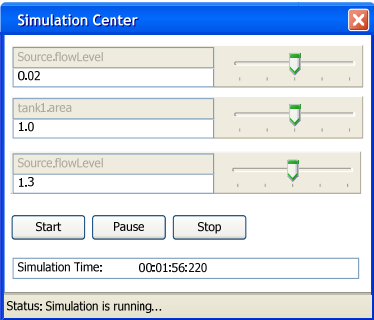- Application demonstrators.

OPENPROD Consortium

27 partners from 5 countries: 11 large industries,
6 SMEs, 5 research institutes, and 5 universities.
Project size: > 90 person years,
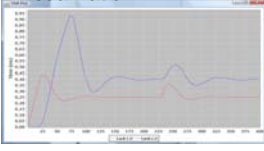Budget: About 11 Mill. €, Duration June 2009 - May 2012.

**Interactive Simulation with OpenModelica
(NEW Prototype developed at EADS)**
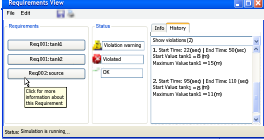
Examples of Simulation Visualization

Simulation Control
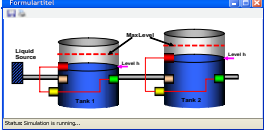
Plot View

Requirements Evaluation View

Domain-Specific Visualization View

UML Action Language Based on UML and Modelica Compilation to MultiCore

- Software/Hardware integrated modeling
- Defining a mapping from UML/SysML to Modelica (current OMG standardization activity)
- Compiling Modelica-based action language for efficient multi-core execution
- Integration in Eclipse
- High speed model transformation engine (MetaModelica)

Using ECLIPSE as Integration Platform in OPENPROD Project
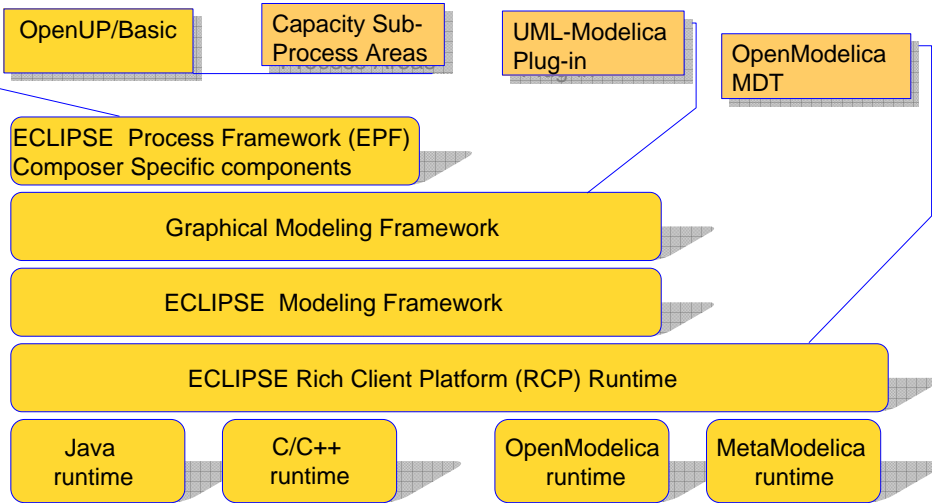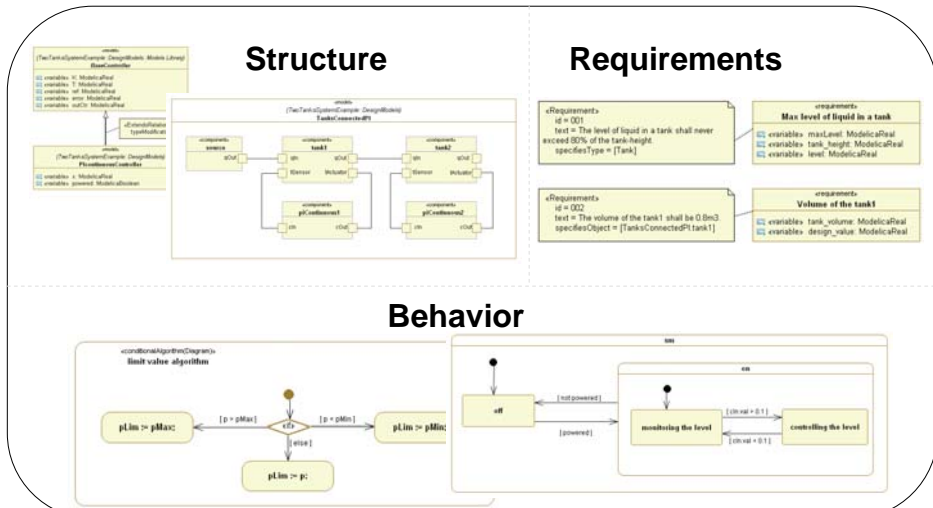
| OpenUP/Basic | Capacity Sub-Process Areas | UML-Modelica Plug-in | OpenModelica MDT |

ECLIPSE Process Framework (EPF) Composer Specific components

Graphical Modeling Framework

ECLIPSE Modeling Framework

ECLIPSE Rich Client Platform (RCP) Runtime

| Java runtime | C/C++ runtime | OpenModelica runtime | MetaModelica runtime |

ModelicaML UML Profile
SysML/UML to Modelica OMG Standardization

- ModelicaML is a UML Profile for SW/HW modeling
  - Applicable to "pure" UML or to other UML profiles, e.g. SysML
- Standardized Mapping UML/SysML to Modelica
  - Defines transformation/mapping for **executable** models
  - Being **standardized** by OMG
- ModelicaML
  - Defines graphical concrete syntax (graphical notation for diagram) for representing Modelica constructs integrated with UML
  - Includes graphical formalisms (e.g. State Machines, Activities, Requirements)
    - Which do not exist in Modelica language
    - Which are translated into executable Modelica code
  - Is defined towards generation of executable Modelica code
  - Current implementation based on the Papyrus UML tool + OpenModelica

ModelicaML: Graphical Notation

Structure

Requirements

Behavior
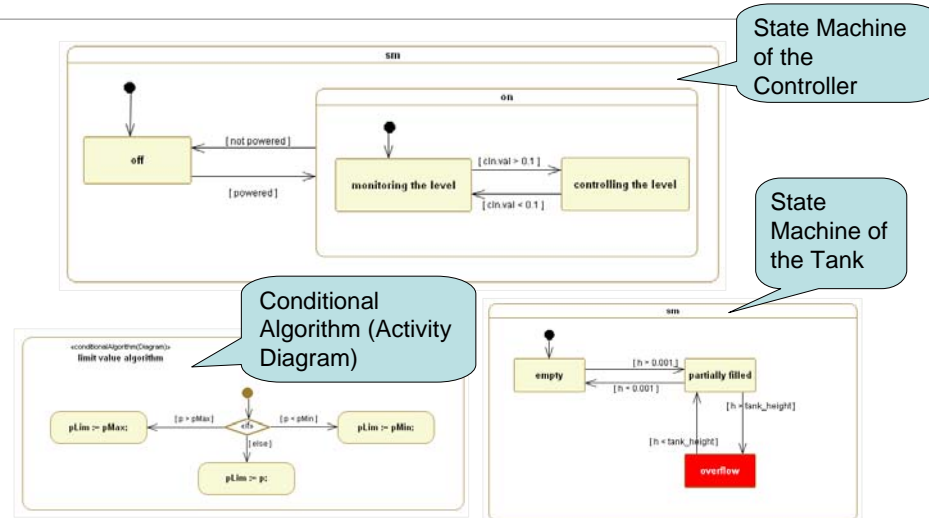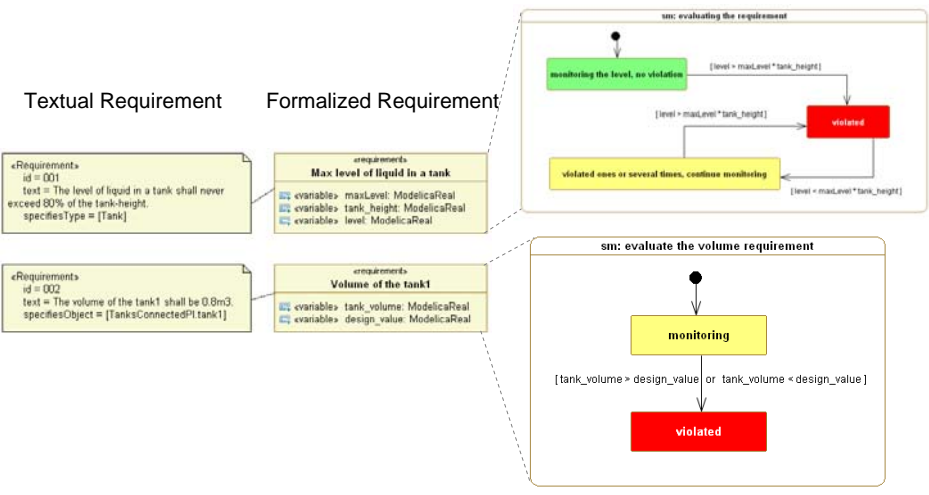
Example: Representation of System Structure

Interconnections

Inheritance

Component s
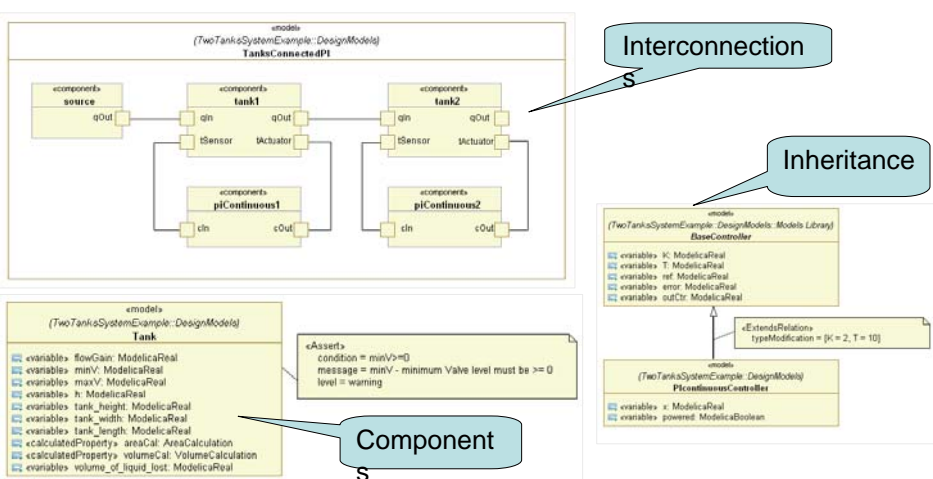
Example: Representation of System Behavior

State Machine of the Controller

State Machine of the Tank

Conditional Algorithm (Activity Diagram)

Example: Representation of System Requirements

Textual Requirement   Formalized Requirement

«Requirement»
id = 001
text = The level of liquid in a tank shall never exceed 80% of the tank-height.
specifiesType = [Tank]

«requirements»
Max level of liquid in a tank

«variable» maxLevel: ModelicaReal
«variable» tank_height: ModelicaReal
«variable» level: ModelicaReal

«Requirement»
id = 002
text = The volume of the tank1 shall be 0.8m3.
specifiesObject = [TanksConnectedPI.tank1]

«requirements»
Volume of the tank1

«variable» tank_volume: ModelicaReal
«variable» design_value: ModelicaReal

sm: evaluating the requirement

monitoring the level, no violation

[level > maxLevel * tank_height]

violated

[level > maxLevel * tank_height]

violated ones or several times, continue monitoring

[level < maxLevel * tank_height]

sm: evaluate the volume requirement

monitoring

[tank_volume > design_value or tank_volume < design_value]

violated

Example: Simulation and Requirements Evaluation

«model»
(*TwoTanksSystemExample::SystemSimulations*)
TankSystemSimulation

«component» dm: TanksConnectedPI
«requirementInstance» r001_tank1: Max level of liquid in a tank
«requirementInstance» r001_tank2: Max level of liquid in a tank
«requirementInstance» r002_tank1: Volume of the tank1

Req. 001 is instantiated 2 times (there are 2 tanks in the system)

tank-height is 0.6m

Req. 001 for the tank2 is violated

Req. 001 for the tank1 is not violated

Plot Window

File   Edit   Insert   Tools   Help

Open   Save   Print   Select   Zoom   Pan   Grid   Hold   Preferences   Active   Image

Plot by OpenModelica

dm.tank1.h
dm.tank2.h
r001_tank1.violated
r001_tank2.violated

time

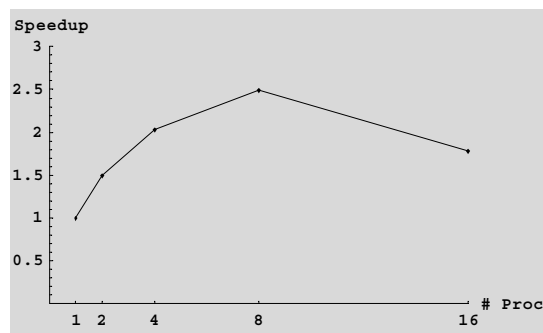# Parallel Execution
Compilation to MultiCore

Integrating Parallelism and Mathematical Models Three Approaches

- **Automatic Parallelization of Mathematical Models (ModPar)**
  - Parallelism over the numeric solver method.
  - Parallelism over time.
  - **Parallelism over the model equation system**
    - ... with fine-grained task scheduling

- **Coarse-Grained Explicit Parallelization Using Components**
  - The programmer partitions the application into computational components using strongly-typed communication interfaces.
    - Co-Simulation, Transmission-Line Modeling (TLM)

- **Explicit Parallel Programming**
  - Providing general, easy-to-use explicit parallel programming constructs within the *algorithmic* part of the modeling language.
    - NestStepModelica, OpenCL, CUDA, ...

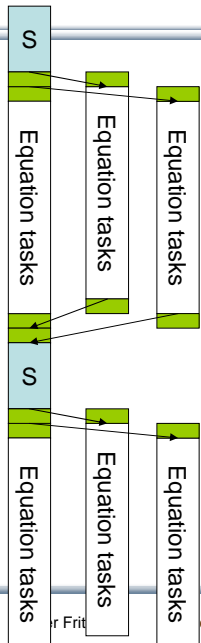# Example – Task Graphs and Parallelized Application
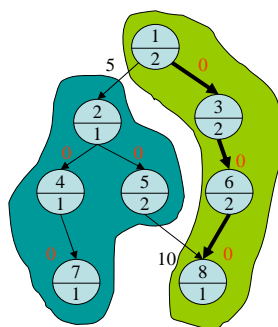

Clustered Task Graph   Thermofluid Pipe Application

Task Merging vs   Approach with Pipelining/Inlining

S

Equation tasks

Equation tasks

Equation tasks

Use a graph rewriting system to merge tasks into larger tasks, based on latency and bandwidth.

Some tasks are duplicated to avoid communication within a step

S

Equation tasks

Equation tasks

Equation tasks

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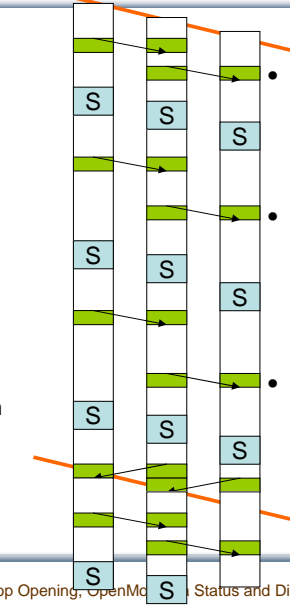
- Try to keep communication as close as possible

- Only communicate in one direction inside a time step.

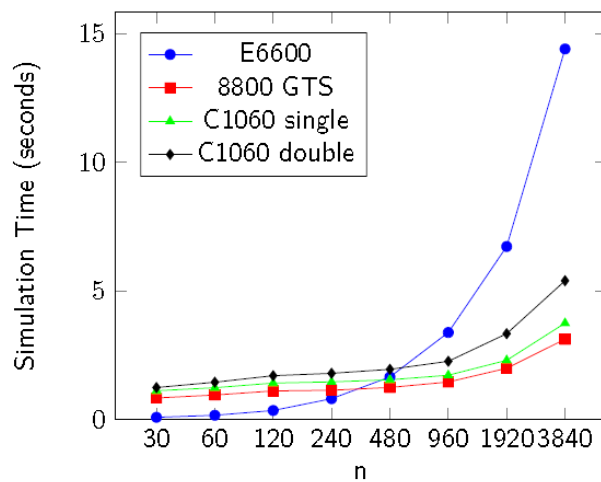- Solver Inlining – distribute the solver across all the processors

Peter Frit   enModelica Annual Workshop Opening, OpenMo   Status and Directions   MODELICA

Recent Speedup Measurements on NVIDIA (nov 2009)
Modelica Model, Generated Code, Function of Problem Size
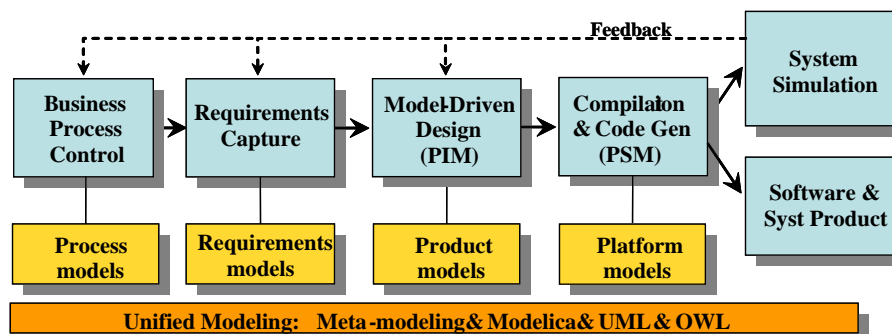

Peter Fritzson   OpenModelica Annual Workshop Opening, OpenModelica Status and Directions   MODELICA

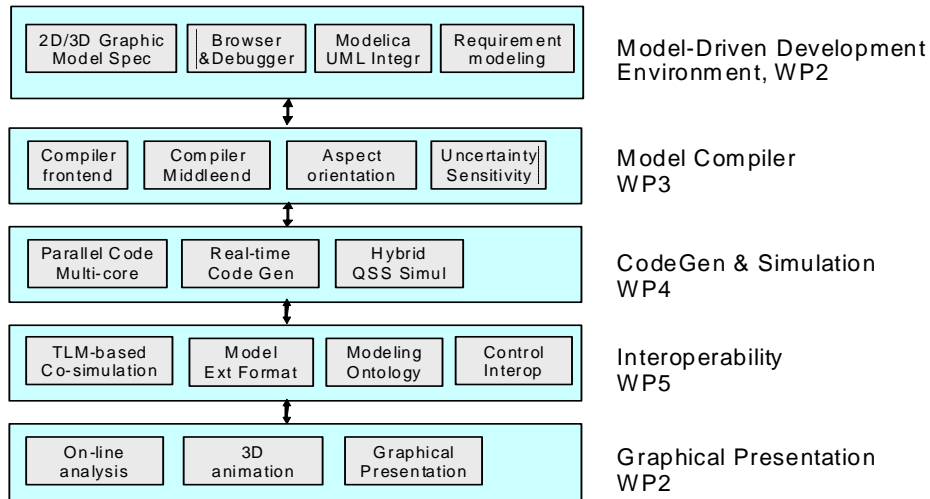## New 2 TeraFlop Parallel Platform to PELAB/LIU

- Just ordered: An NVIDIA Fermi 2050 2 Teraflop peak parallel platform, delivery in May-Sept 2010.

- Use, e.g. in research on compiling Modelica to MultiCore

OPENPROD - Framework

OPENPROD Vision of unified modeling framework for model-driven product development from platform independent models (PIM) to platform specific models (PSM)

OPENPROD System Structure

2D/3D Graphic Model Spec — Browser &Debugger — Modelica UML Integr — Requirement modeling	Model-Driven Development Environment, WP2
Compiler frontend — Compiler Middleend — Aspect orientation — Uncertainty Sensitivity	Model Compiler WP3
Parallel Code Multi-core — Real-time Code Gen — Hybrid QSS Simul	CodeGen & Simulation WP4
TLM-based Co-simulation — Model Ext Format — Modeling Ontology — Control Interop	Interoperability WP5
On-line analysis — 3D animation — Graphical Presentation	Graphical Presentation WP2

Current OPENPROD Expanded to 28 Partners

- Siemens Industrial TurboMachinery AB
- Siemens AG, Sector Energy
- Bosch-Rexroth AG
- SKF Sverige AB
- Nokia
- Pöyry
- LMS Imagine S.A.
- Electricité de France
- Equa Simulation AB
- MathCore Engineering AB
- TLK Thermo GmbH

- IFP
- VTT
- Fraunhofer FIRST
- INRIA Rocquencourt
- CEA LIST
- Linköping University
- Fachhochschule Bielefeld
- ETH Zürich
- Technische Universität Braunschweig
- Metso Automation
- Appedge

- University of Lyon INSA
- PSA
- EADS
- Plexim
- XRG Simulation
- Modelon

OpenModelica Main Events Summary 2009

- Jan 2009. OpenModelica 1.4.5 released.
- Feb 2009. First Annual OpenModelica Workshop in Linköping, Sweden.
- March 2009. OSMC has increased to 21 organizational members
- June 2009. Start of OPENPROD ITEA2 11 million €, 27-partner project including substantial OpenModelica development.
- Sept 2009. Most comment-preserving unparser/refactoring functionality completed.
- Sept 2009. OpenModelica at Modelica conference.
- Oct 2009. OpenModelica 1.5 RC1 released, including improved Modelica library flattening, new Java-interface, Python interoperability, enhanced ModelicaML UML-Modelica profile prototype.
- Complete the new solver interface
- Dec 2009. OSMC has increased to 28 members.
- Draft OpenModelica Text template language for producing code generators. Used to develop next generation C and C# code generators from OpenModelica.

Conclusions

- OpenModelica work accelerated during the past year
- The Open Source Modelica Consortium expanded from 19 to 28 organizational members
- Good progress towards supporting the MultiBody and Media/Fluid libraries, but needed work was underestimated. Now more people (3-4) working on the compiler frontend since Dec 2009. Also increasing work on compiler backend.
- Good prospects for the future – towards a standard high quality open source Modelica implementation in Modelica, and increasing tool support for integrated systems engineering.

Questions?

www.openmodelica.org