Technical Overview of OpenModelica and its Development Environment

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www.OpenModelica.org
Outline

- **OpenModelica**
  - What is OpenModelica?
  - The past

- **OpenModelica Technical Overview**
  - OMC, OMSHell, OMNotebook,
  - OMEdit, ModelicaML, SimForge

- **OpenModelica Development Environment**
  - MetaModelica (RML/OMC)
  - The Eclipse Environment (MDT)

- **OpenModelica Latest Developments (2013-2014)**
OpenModelica is ... **its developers**

Thank you!

asodja, sjoelund.se, sebco011, lochel, wbraun, niklwors, hubert.thieriot, petar, perost, Frenkel TUD, Unknown, syeas460, adeas31, ppriv, ricli576, haklu, dietmarw, levs, mahge930, x05andfe, mohsen, nutaro, x02lucpo, florosx, x06hener, x07simbj, stebr461, x08joekl, x08kimja, Dongliang Li, jhare950, x97darva, krsta, edgarlopez, hanke, henjo, wuzhu.chen, fbergero, harka011, tmstuomas, bjozacz, AlexeyLebedev, x06klajj, ankar, kajny, vasaie.p, niemisto, donida, hkiel, davbr, otto@mathcore.com, Kaie Kubjas, x06krino, afshe, x06mikbl, leonardo.laguna, petfr, dhedberg, g-karbe, x06henma, abhinnk, azasi, x02danhe, rruusu, x98petro, mater, g-bjoza, x02kajny, g-pavgr, x05andre, vaden, jansilar, ericmeyers, x05simel, andsa, leist, choeger, Ariel.Liebman, frisk, vaurich, mwaltner, mfiller, ptauber, casella, vitalij, hkiel, jank, adrpo
What is OpenModelica? (I)

- Advanced Interactive Modelica compiler (OMC)
  - Supports MLS v. 3.1/MSL v. 3.2.1
- Basic and advanced environments for creating models
  - OMShell - an interactive command handler
  - OMNotebook - a literate programming notebook
  - OMEdit - Open Modelica Connection Editor
  - OMPlot - Open Modelica Plotting
  - OMOptim - Open Modelica Optimization Editor
  - MDT - an advanced textual environment in Eclipse
What Is OpenModelica? (II)

- Advanced Eclipse-based Development Environment
- Modelica Development Tooling (MDT) - started in 2005
  - Code Assistance, Debugging, Outline & a lot more
  - *Used heavily for OpenModelica development*
  - Used in many OpenModelica Development Courses
- ModelicaML UML/SysML integration
What is OpenModelica? (III)

- Open-source community services
  - Website and Support Forum
  - Version-controlled source base
  - Trac with bug database
  - Development courses
  - Mailing lists
What is OpenModelica? (IV)

- Open-source community services
- Extensive testing (unit & library coverage: MSL 3.2.1, ModelicaTest 3.2.1, PetriNet, Buildings, PowerSystems, OpenHydraulics, ThermoPower, and ThermoSysPro) with interactive result comparison
- ~2700 tests ran on each commit via Hudson (3 test servers currently)
  - Linux (GCC & CLANG), Windows (MinGW GCC), Mac OS (GCC)
  - Automatic nightly builds for Window & Linux & Mac OS
What is OpenModelica? (V)

- An incubator platform for research
  - 6 PhDs since 2004 (Debugging, Parallelization, PDEs Extensions)
  - 30 Master’s theses since 2004
  - Both the students and the project benefit

- Master theses at PELAB 2006-2014
  - Refactoring/Parsing and Language extensions
  - UML/SysML view of Modelica code
  - 2D and 3D visualization tools
  - Static and runtime debugging tools
  - Advanced code generation and parallelization of simulation code
  - Bootstrapping and Java Interface
  - Function pointers
  - NVIDIA for Cuda and OpenCL parallel simulation
  - OMEdit - Modelica Connection Editor
  - OMWeb - server based Modelica simulation for teaching
  - OMCcc parser

- External Master theses
  - Model based diagnostics at ISY (Dep. Of Electrical Engineering)
  - Monte-Carlo simulation of Satellite Separation Systems at SAAB
  - Interactive Simulations (EADS)
  - Additional Solvers + Event handling (FH-Bielefeld)
  - EADS - ModelicaML

- A Base for commercial and open source products
  - MathCore AB, Bosch Rexroth, InterCAX (MagicDraw SysML), VTT, Equa, Evonik
OpenModelica Roadmap - Past

1997 - started as a master thesis
2003 - first usable internal version
2004 - first external version: OpenModelica 1.1
2005 - more development: OpenModelica 1.3.1

2006 - major milestone
- Translated the whole compiler to MetaModelica
- Integrated Development Environment for the compiler
- OpenModelica website started
- Moved the code repository to Subversion management
- Extended the OpenModelica environment with new tools
- 4 versions released during the year
- External people start using OpenModelica
  - ~ 200 downloads/month
  - first development course at INRIA
OpenModelica Roadmap - Past

2007 - continued development and community involvement

- Improvement in website, support and documentation
- Answered ~1000 questions on the forum
- Portability is highly improved, ported to 4 platforms
  - Linux, Mac, Solaris, Windows (version 1.4.3)
- Improvement of the compiler development tools in Eclipse
- OpenModelica Community starts to react
  - contribute code & report bugs & request enhancements & participate in answering questions in the OpenModelica forum
  - participate at courses and workshops
- New server acquired for better community services
- Increased usage: ~600 downloads/month
- Open Modelica Consortium created in December 4
  - 4 months of work
  - 9 organizations as members already (3 Universities, 6 Companies)
  - discussions are ongoing with other 6 companies
OpenModelica Roadmap - Past

2008 - Further work on the compiler
▪ Release 1.4.4 and 1.4.5
  ▪ Linux, Mac, Solaris, Windows
▪ New Solver Interface
▪ Refactoring
▪ Dynamic loading of functions
▪ Merging of MathCore front-end code
▪ 744 commits in Subversion
▪ Other things I don’t remember
OpenModelica Roadmap - Past

2009

- Work mainly happened in OSMC (partially on a non-public branch)
  - **Front-end**
    - Refactoring (OSMC)
    - Enumerations (OSMC)
    - Java Interface and Bootstrapping (Martin Sjölund)
    - MultiBody flattening (OSMC)
    - Constraint connection graph breaking (VTT + OSMC)
    - Support for Modelica 3.x and 3.x annotations (OSMC)
  - **Back-end**
    - Tearing in the back-end (Jens Frenkel)
    - Template Code Generation and CSharp backend (Pavol Privitzer, Charles University Prague)
    - Interactive Simulations (EADS)
    - C++ Code generation (Bosch Rexroth)
    - Java Interface and Bootstrapping (Martin Sjölund)
    - Additional Solvers + Events (Willi Braun, FH-Bielefeld)
  - **General**
    - New ModelicaML + SysML prototype (EADS)
    - 1144 commits in subversion (Since 2009 to February 8, 2010)
    - Bug fixes (OSMC)
    - Release 1.5.0 and 1.5.0-RC_X (Linux, Mac, Solaris, Windows)
  - More things I don’t remember
OpenModelica Roadmap - Past

2010 - 2011

- Support for Modelica Standard Library 3.1 (Media & Fluid in works)
- Front-end
  - MultiBody flattening (OSMC)
  - Support for Modelica 3.x and 3.x annotations (OSMC)
  - Performance Enhancements
  - Stream connectors
  - Media & Fluid work is on the way
- Back-end
  - Back-end redesign (Jens, Willi, Martin, Per, Adrian, Kristian, Filippo)
  - Tearing in the back-end (Jens Frenkel)
  - Template Code Generation and CSharp backend (Pavol Privitzer, Charles University Prague)
  - Interactive Simulations (EADS)
  - C++ Code generation (Bosch Rexroth)
  - Additional Solvers + Events + Linearization (Willi Braun, FH-Bielefeld)
- General
  - OMEdit - new connection editor
  - Bootstrapping OMC (90% finished)
  - 2550 commits in subversion from 2010 to Feb. 7, 2011 (double than 2009-2010)
  - Bug fixes ~300+ (OSMC)
  - Release 1.6.0 (Linux, Mac, Windows)
  - Downloads Windows (~16434), Linux (~8301), Mac (~2816)
- More things I don’t remember
OpenModelica Roadmap - Past

2012 - 2013

- Support for Modelica Standard Library 3.2.1 including Media & Fluid

- Front-end
  - Performance Enhancements
  - Media & Fluid work
  - Operator overloading
  - New instantiation module started

- Back-end
  - Modular back-end with more optimization modules (Jens, Willi, Martin)
  - New simulation runtime redesign (Willi, Lennart, Jens, Martin, Adrian)
  - C++ Code generation (Bosch Rexroth)
  - FMI export & import
  - Initialization, Jacobians (Lennart Lochel, Willi Braun, FH-Bielefeld)
  - Support for parallelization (Martin)
  - Parallel extensions in functions

- General
  - Uncertainties support (OpenTURNS connection & Data reconciliation)
  - MDT GDB debugging based on GDB and the bootstrapped compiler
  - OMEdit - improvements
  - Bootstrapping OMC (100% finished) using Boehm GC
  - 3909 commits in subversion from 2012 to Feb. 4, 2013
  - 2000 forum posts (questions and answers)
  - Bug fixes ~247+ (OSMC)
  - Release 1.9.0 (Linux, Mac, Windows)
  - Downloads Windows (~45307), Linux (~15543), Mac (~5367)

- More things I don’t remember
OpenModelica Testing (I)

- 2014-02-03 r18909 - total 274 - build 269 (97%) - sim 248 (92%)

![Graph showing coverage over time with legend: Target: 274, Compile: 269, Simulate: 248]
OpenModelica Testing (II)

- 2014-02-03 r18909 - total 431 - build 414 (91%) - sim 385 (81%)

Modelica Test 3.2.1 Coverage

Legend:
- Target: 431
- Compile: 414
- Simulate: 385
- **Mature code base** (http://build.openmodelica.org/omc/statsvn_trunk/)
- ~ 7000K lines of code and tests
Outline

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  - The past

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- OpenModelica Development Environment
  - MetaModelica (RML/OMC)
  - The Eclipse Environment

- OpenModelica Latest Developments (2011-2012)
OMShell & OMNotebook

Demo?

OpenModelica 1.4.3
Copyright 2002-2006, PELAB, Linkoping University

To get help on using OMShell and OpenModelica, type "help()" and press enter.

>> loadModel(Modelica)
true

>> loadFile("C:/OpenModelica.4.3/testmodels/BouncingBall.mo")
true

>> simulate(BouncingBall, stopTime=3)
record
  resultFile = "BouncingBall_res.plt"
end record

>> plot(h)
true

DrModelica
Modelica Edition

Van der Pol Model

This example describes a Van der Pol oscillator. Notice that here the keyword model is used instead of class with the same meaning. This example contains declaration of two state variables $x$ and $y$, both of type Real and a parameter constant lambda, which is a so-called simulation parameter. The keyword parameter specifies that the variable is constant during simulation time, but can later be value initialized before a run or between runs. Finally, there is an equation section starting with the keyword equation, containing two mutually dependent equations that define the dynamics of the model.

```
model VanDerPol
  "Van der Pol oscillator model"
  Real x(start = 1);
  Real y(start = 1);
  parameter Real lambda = 0.3;
  equation
    dx/dt = y;
    dy/dt = -x + lambda*(1 - x^2)*y;
end VanDerPol;
```

1 Getting Started

1.1 Simulation of Van der Pol

To illustrate the behavior of the model, we give a command to simulate the Van der Pol oscillator during 25 seconds starting at time 0.

```matlab
simulate(VanDerPol, startTime=0, stopTime=25);
```
OMEdit - Demo? Maybe a movie!
The OMC Compiler

- Implemented mainly in MetaModelica and C/C++
- The compiler has 230 packages
// Parse the file and get an AST back
ast = Parse.parse(modelicaFile);

// Elaborate the file
scode = SCode.elaborate(ast);

// flatten the simplified code
(cache, dae1) = Inst.instantiate(Env.emptyCache, scode);

// Call the function that optimizes the DAE
optimizeDae(scode, ast, dae, dae, lastClassName);
Outline

- OpenModelica
  - What is OpenModelica?
  - The past and present

- OpenModelica Technical Overview
  - OMC, OMShell, OMNotebook
  - OMEdit, ModelicaML, SimForge

- OpenModelica Development Environment
  - MetaModelica
  - The Eclipse Environment

- OpenModelica Latest Developments (2013-2014)
- **OMC**
  - Implemented mainly in MetaModelica and C/C++

- **Modelica**
  - classes, models, records, functions, packages
  - behavior is defined by equations or/and functions
  - equations
    - differential algebraic equations and conditional equations

- **MetaModelica extensions**
  - local equations
  - pattern equations
  - match expressions
  - high-level data structures: lists, tuples, option and uniontypes
OpenModelica Context

Server: Main Program
Including Compiler, Interpreter, etc.

SCode

Inst

Ceval

Parse

Corba

Client: Graphic Model Editor

Client: OMSH shell
Interactive Session Handler

Client: Eclipse Plugin

Typed Checked Command API

system

plot

etc.

SCode

Interactive

Untyped API
The MDT Eclipse Environment (II)

- .mo file
  - OMC Compiler
  - Small Modelica Parser
    - AST Information
    - Modelica model
      - Modelica Browser
      - Modelica Editor
      - Modelica Code Assistant
      - Eclipse
  - MetaModelica Builder
    - MetaModelica Build console
      - MetaModelica Debugging
  - OMC Compiler Bootstrapping
    - Code compiled with GDB symbols
      - MMC Compiler
      - MetaModelica GDB Debugging
The MDT Eclipse Environment (III)

- .mo file
- OMC (OMC Compiler)
- Bootstrapped Compiler
- Executable + GDB
- MetaModelica
- GDB Debugging
- Modelica Editor
- Eclipse
Creating Modelica projects (I)

Creation of Modelica projects using wizards
Creating Modelica projects (II)

Modelica project
Creation of Modelica packages using wizards
Creating Modelica classes, models, etc, using wizards
Code browsing

Error detection (I)

Parse error detection on file save
Error detection (II)

Semantic error detection on compilation
Code assistance (I)

Code Assistance on imports
Code assistance (II)

Code Assistance on assignments
Code Assistance on function calls
Code indentation

```java
// Van der Pol model

tmodel VanDerPol "Van der Pol oscillator model"
import Modelica.Math;
Real x(start=1);
Real y(start=1);
parameter Real lambda = 0.3;
parameter Real e = Modelica.Constants.e;

equation
    der(x) = y;
    der(y) = -x + lambda*(1 - x^2)*y;
end VanDerPol;
```
Code Outline and Hovering Info

Code Outline for easy navigation within Modelica files

Identifier Info on Hovering
Eclipse Debugging Environment

- Type information for all variables
- Browsing of complex data structures
- GDB based
OMEdit Debugging Environment
Eclipse environment for ModelicaML

1. System Modeling with ModelicaML
2. Modelica Code Generation
3. System Simulation with Modelica Tools

- Tutorial tomorrow at ModProd 2014!
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  - MetaModelica
  - The Eclipse Environment

- OpenModelica Latest Developments (2013-2014)
2013 - 2014 - Most focus on libraries support & performance

- MSL 3.2.1 (98% build/90% simulate), ModelicaTest 3.2.1, PetriNet, Buildings, PowerSystems, OpenHydraulics, ThermoPower, and ThermoSysPro
- AVM project - FANG Darpa competition

**Front-end & Back-end & Simulation Runtime**

- New instantiation module (Lookup, Flattening, Connection Handling) - continued work
- Further back-end improvements
- FMI support
- Several Simulation Runtimes (C, C++, C#, Java, XML, Adevs, QSS, FMU, JS)
- OMEdit - Improvements & Integrated debugging support
- Compiler support for optimization
- Automatic differentiation of algorithms and functions
- HpCom - parallelization of model code
- Backend redesign for improved scalability and memory
- Bootstrapping OMC improvements, separate compilation, ready for wide use
- Simulating models in the browser

**General**

- ModelicaTest compliance testsuite for Modelica Association
- 3195 commits in subversion from 2013 to Feb. 4, 2014
- Bug fixes
- Release 1.9.1 (Linux, Mac, Windows)
Latest Developments (2013-2014)

- **Front-end issues in works since 1.9.0**
  - support for calling function via instance (MultiBody, VehicleDynamics, PowerTrain)
    \[
    \text{world.gravityAcceleration(\ldots)}
    \]
  - handle same type with different redeclares (Media & Fluid)
    \[
    T \ x1(\text{redeclare function } f = f1) \\
    T \ x2(\text{redeclare function } f = f2)
    \]
  - better support for package constants (ExternalMedia, Media & Fluid)
  - fix remaining redeclare issues (Media.Examples.R134*)
  - support for querying the instance of a flattened model
    needed for OMEdit handling of model structure
  - support for choicesAllMatching annotation (subtyping relationship of models/comps)
    needed for OMEdit handling of replaceable components/models
  - scalability & performance
    basically do things once and not several times
    separate lookup, modifier application, typing, array expansion, equation & connection handling, etc.
Thank You!
Questions?

asodja, sjoelund.se, sebco011, lochel, wbraun, niklwors, hubert.thieriot, petar, perost, Frenkel TUD, Unknown, syeas460, adeas31, ppriv, ricli576, haklu, dietmarw, leva, mahge930, x05andfe, mohsen, nutaro, x02lucpo, florosx, x06hener, x07simbj, stebr461, x08joekl, x08kimja, Dongliang Li, jhare950, x97davka, krst, edgarlopez, hanke, henjo, wuzhuchen, fbergero, harka011, tmtuomas, bjozac, Alexeylebedev, x06klasj, ankar, kajny, vasaie.p, niemisto, donida, hkiel, davbr, otto@mathcore.com, kaie kubjas, x06krino, afshe, x06mikbl, leonardo.laguna, petfr, dhedberg, gkarbe, x06henma, abhinnk, azazi, x02danhe, rruusu, x98petro, mater, g-bjoza, x02kajny, g-pavgr, x05andre, vaden, jansilar, ericmeyers, x05simel, andsa, leist, choeger, ariel.liebman, frisk, vaurich, mwalther, mtiller, ptauber, casella, vitalij, hkiel, jank, adrpo

OpenModelica Project
http://www.OpenModelica.org
Funny Facts

- 2012 (left) vs. 2013 (right)

/trunk: Activity by Hour of Day for adrpo

/trunk: Activity by Day of Week for adrpo