Technical Overview of OpenModelica and its Development Environment

Adrian Pop

2017-02-06

Open Source Modelica Consortium
Programming Environment Laboratory
Department of Computer and Information Science
Linköping University

www.OpenModelica.org
Outline

- OpenModelica
  - What is OpenModelica?
  - The past

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

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

- OpenModelica Latest Developments (2016-2017)
OpenModelica is ... **its developers, testers, bug reporters, contributors** and **OSMC members**

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, x07simby, stebr461, x08joekl, x08kimja, Dongliang Li, jhare950, x97davka, krsta, edgarlopez, hanke, henjo, wuzhu.chen, 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, g-karbe, 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, rfranke, mflehmig, crupp2, kbalzereit, marchartung, adrpo
What is OpenModelica? (I)

- Advanced Interactive Modelica compiler (OMC)
  - Supports MSL v. 3.2.1/3.2.2/MSL trunk
- Basic and advanced environments for creating models
  - OMShell - an interactive command handler
  - OMNotebook - a literate programming notebook
  - OMEdit - Connection Editor, *Transformational and Algorithmic Debugger, 3D Viewer*
  - OMPlot - OpenModelica Plotting
  - OMOptim - OpenModelica Optimization Editor
  - OMPython - OpenModelica Python Environment
  - 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
  - *Slowly replaced by OMEdit*
- ModelicaML UML/SysML integration
What is OpenModelica? (III)

- Open-source community services
  - Website and Support Forum
  - Source versioning (github.com)
  - Trac with bug database
  - Development courses
  - Mailing lists
What is OpenModelica? (IV)

- Open-source community services
  - Extensive testing (unit & library coverage: MSL 3.2.x, ModelicaTest 3.2.x, PetriNet, Buildings, PowerSystems, OpenHydraulics, ThermoPower, and ThermoSysPro) with interactive result comparison
  - ~3001 tests ran on each commit via Hudson (5 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
  - 9 PhDs since 2004 (Debugging, Parallelization, PDEs Extensions)
  - 36 Master’s theses since 2004
  - Both the students and the project benefit
- Master theses at PELAB 2006-2016
  - 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
  - PDE-solver using ParModelica
- 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, ABB
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
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
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 Roadmap – Past

- 2014 - 2016 - Most focus on libraries support & performance
  - MSL 3.2.1 (100% build/98% simulate), ModelicaTest 3.2.1, PetriNet, Buildings, PowerSystems, OpenHydraulics, ThermoPower, and ThermoSysPro
  - Switch to bootstrapped compiler

- Front-end, Back-end, Simulation Runtime, Graphical Clients
  - Development switched to bootstrapped compiler since November 2014
  - Partially new graph-based front-end with better support for libraries
  - Improved back-end: initialization, system solving, parallelization, cse optimization, dynamic optimization
  - Faster and much more user friendly OpenModelica Connection editor

- General
  - ~9000 commits in subversion from Feb. 2014 to Feb., 2016
  - Bug fixes
  - Release 1.9.2 (Linux, Mac, Windows)
2017-02-05 v1.12-dev - total 278 - build 276 (99%) - sim 274 (98%)
2017-02-05 v1.12-dev - total 440 - build 432 (97%) - sim 423 (96%)
Moved the source code to github May 2015
Mature code base: [https://github.com/OpenModelica](https://github.com/OpenModelica)
~9000K lines of code and tests

From Feb 2016 - Feb 2017
- 60 contributors - up by 5 contributors
- 1420 commits (OMCompiler)
OpenModelica Statistics (II)

Feb 1, 2016 – Feb 5, 2017
Contributions to master, excluding merge commits
Outline

- OpenModelica
  - What is OpenModelica?
  - The past

- OpenModelica Technical Overview
  - OMC, OMSHELL, OMNotebook,
  - OMEdit, ModelicaML

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

- OpenModelica Latest Developments (2016-2017)
OMShell & OMNotebook

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:/OpenModelica1.4.3/testmodels/BouncingBall.mo")
true

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

>> plot(h)
true

DrModelica Modelica Edition

This example describes a Van der Pol oscillator. Notice that the keyword model is used instead of class with
the same meaning. This example contains declarations 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
continuous during a simulation run, but can have its 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
    Real xstart = 1;
    Real ystart = 1;
    parameter Real lambda = 0.1;
    equation
    der(x) = y;
    der (y) = -x + lambda*(1 - x^2)*y;
end VanDerPol;

Van der Pol Model

1 Getting Started

IMPORTANT
If you end a command returned in an online help change the direction of the cd() command.

Plot by OpenModelica
The OMC Compiler

- Implemented mainly in MetaModelica and C/C++
- The compiler has 258 packages
// Parse the file and get an AST back
ast = Parse.parse(modelicaFile);

// Translate to simplified C code
scode = SCode.absyn2SCode(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);
OpenModelica

- What is OpenModelica?
- The past and present

OpenModelica Technical Overview

- OMC, OMSH-shell, OMNotebook
- OMEdit, ModelicaML, SimForge

OpenModelica Development Environment

- MetaModelica
- The Eclipse Environment

OpenModelica Latest Developments (2016-2017)
- **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 union types
OpenModelica Context

Server: Main Program Including Compiler, Interpreter, etc.

Parse

Corba

Client: Graphic Model Editor

Client: OMSHELL Interactive Session Handler

Client: Eclipse Plugin

SCode

Interactive

Inst

Ceval

system

plot

etc.

Untyped API

Typed Checked Command API
The MDT Eclipse Environment (I)

Eclipse Platform

- Workbench IDE UI
- Team
- Compare/Search
- Workspace/Resources
- Update
- Forms
- Outline and Property Views
- Workbench UI (Editors, Views, Perspectives)
- Help
- SWT
- Platform Runtime (based on OSGI)

Modelica Browser
Modelica Editor
Modelica Code Assistant
MetaModelica Debugging
Modelica Perspective
Creating Modelica projects (I)

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

Creation of Modelica classes, models, etc., using wizards
Parse error detection on file save
Semantic error detection on compilation
Code Assistance on imports
Code assistance (II)

Code Assistance on assignments
Code Assistance (III)

Code Assistance on function calls

```plaintext
// Van der Pol model

model 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;  // Real sin(SI.Angle u)
y = Modelica.Math.sin(
der(y) = -x + lambda*(1 - x*x)*y;
end VanDerPol;
```
Code indentation

```modelica
// Van der Pol model
model 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
Tutorial 1 - tomorrow at ModProd 2017!
Eclipse environment for ModelicaML

1. System Modeling with ModelicaML

2. Modelica Code Generation

3. System Simulation with Modelica Tools
Outline

- OpenModelica
  - What is OpenModelica?
  - The past

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

- OpenModelica Development Environment
  - MetaModelica
  - The Eclipse Environment

- OpenModelica Latest Developments (2016-2017)
Latest Developments (2016-2017) (I)

- 2016 - 2017 - focus on libraries support, performance and usability
  - MSL 3.2.2 (98% build/97% simulate), ModelicaTest 3.2.2, PetriNet, Buildings, PowerSystems, OpenHydraulics, ThermoPower, and ThermoSysPro, Modelica_Synchronous

- Front-end, Back-end, Simulation Runtime, Graphical Clients
  - Improved support for synchronous language features and state machines
  - Better support for some libraries in the front-end and back-end
  - Improved back-end: initialization, system solving, parallelization, cse optimization, dynamic optimization
  - Performance & scalability improvements, ScalableTestSuite 10 times faster
  - Faster and much more user friendly OpenModelica Connection Editor
    - 3D viewer
    - Transformational & Algorithmic Debugger
    - Compiler development support
    - Code folding, minimal difference on graphical editing to support source versioning
    - Support for replaceable will be available for testing later this week
  - Bug fixes to FMI support for Model Exchange and Co-Simulation

- General
  - Feb 2015 - Feb 2016
    - 60 contributors - up by 5 contributors
    - 1420 commits (OMCompiler)
  - Bug fixes
  - 64bit and 32bit versions available
  - Release 1.9.7 (Linux, Mac, Windows), Release 1.11.0 today (beta4 available)
**Improved scalability**
- faster compilation speed & reduced memory requirements
- 2015 - OMC handles ~60000 equations in 700 seconds
- 2017 - OMC handles ~60000 equations in 45 seconds (~15x faster)

**New Front-End**
- Work is progressing on the new front-end ~50% complete, more developers are working in parallel (see #4138 on Trac)
- 20 times faster or more, much more scalable both in time and memory (no array expansions, no expansion of for loops in equations)
- The new front-end will also bring better support for libraries also (the last 20% we are missing, mostly because of issues with package constants and complex redeclares)
- Developed in line with MCP-0019: Flattening

**OMEdit**
- Much more robust, doesn’t crash that often anymore
- We get crash reports with stack traces when users experience a crash
Thank You!
Questions?

asodja, sjoelund.se, sebco011, lochel, wbraun, niklwors, hubert.thieriot, petar, perost, Frenkel TUD, Unknown, syeas460, adeas31, ppriiv, ricli576, haklu, dietmarw, levsy, mahge930, x05andfe, mohsen, nutaro; x02lucpo, florosx, x06hener, x07simbj, stebr461, x08joekl, x08kimja, Dongliang Li, jhare950, x97davka, krsta; edgarlopez, hanke, henjo; wuzhu. chen, 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, g-karbe, 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, rfranke, mflehmig, crupp2, kbalzereit, marchartung, adrpo.
- **OMC**
  - The OMC API is quite inefficient and hugely non-homogeneous

- **OMEdit**
  - Still slow for displaying some models
  - Doesn’t understand Modelica code directly, needs to talk with OMC
  - Is missing basic features for models using redeclare & replaceable