MultiBody Simulation with OpenModelica and MathModelica

Gerhard Schmitz, Peter Aronsson, Adrian Pop

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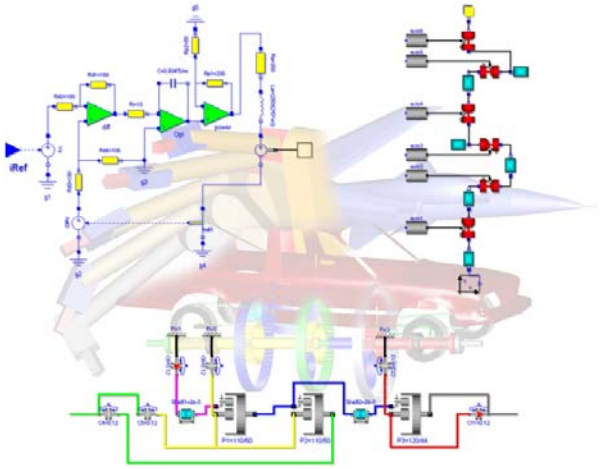
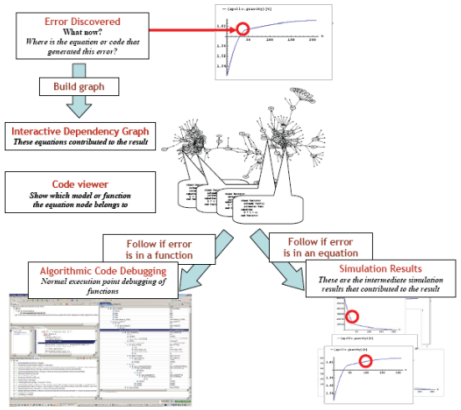
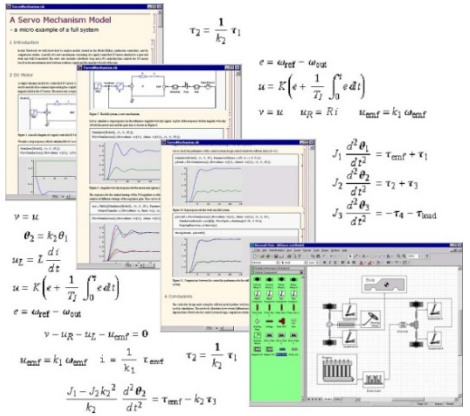
www.OpenModelica.org







OpenModelica

MODELICA

Own experiences with libraries

Gerhard Schmitz, Applied Thermodynamics
Institute of Thermo-Fluid Dynamics
Hamburg-Harburg, University of Technology

- **AClib** (precursor of AirConditioning®, Torge Pfafferott)
- Contributions to **Modelica_Fluid** and **AirConditioning** (Katrin Proelss)
- **ACClib** (ECS of Aircrafts, Karin Dietl, Jens Vasel, Philipp Jordan)
- **KATO** (CabinFlow in Aircrafts, Henning Knigge)
- **Thermal Separation Library** (Karin Dietl, Andreas Joos)
- **DIM** (Water vapor transport, Andreas Joos, Stefan Wischhusen, XRG)
- Energy Nets (Stefan Storace, Lichtblick)
- Battery cooling systems (based on AirConditioning, Imke Krüger)
- Building HVAC library (Jan Wrobel, Wilson Casas)

Demands and users

Reasons for using Modelica libraries

- Developing of new systems (pre development)
- Modefication and optimization of exiting systems
- Understanding the dynamic behavior of complex systems

Different users:

- Drag and drop users
- Modelling users
- Library developers

Library issues – level of importance

TECHNISCHE THERMODYNAMIK
Technische Universität Hamburg-Harburg

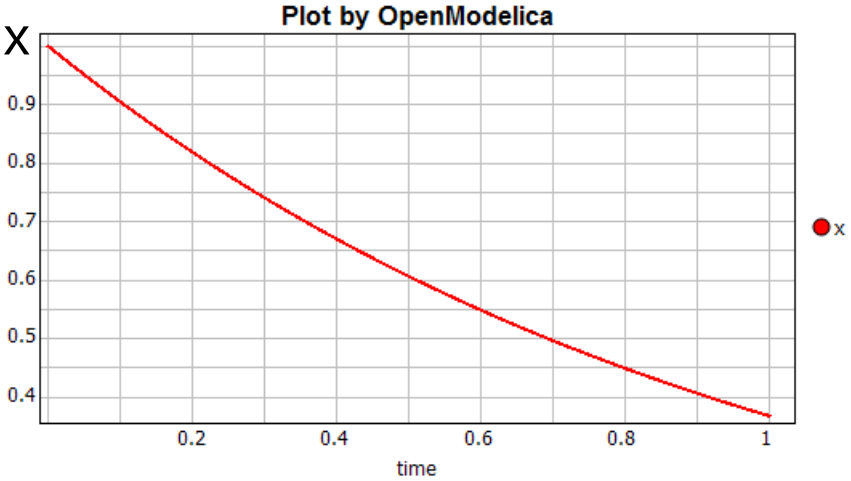
		Standard Appl. (MSL)	Mechan. Appl. (MBL)	Electrical Appl. (SPICE3-ML)	ThermoFluid Appl. (Modelica_Fluid)	Chemical Appl. (ThSepL)	Biochem. Appl. (Petrinet-L)	
User	**Graphical User interface**	o	++	++	+	o	o	Library
	Numerical Stability in diff. environments	++	++	++	++	++	++	
	Initialisation procedures	--	o	o	++	++	+	
	Steady state solutions	--	-	-	++	++	+	
Developer	**Structure**	+	+	+	++	++	++	
	Modelica Conformism	++	+	+	+	o	o	Compiler
	Debugging Tools	o	++	++	++	++	++	

++ very important + important o nice to have - not important - - needless

Most important: error messages (1)


```
class HelloWorld
  Real x(start = 1);
  parameter Real a = 1;
equation
  der(x) = - a * x;
end HelloWorld;
```

```
>> simulate(HelloWorld)
record SimulationResult
resultFile = "HelloWorld_res.plt"
end SimulationResult;
```




```
class HelloWorld
  Real x(start = 1);
  parameter Real a = 1;
equation
  der(x) = - a * x / 0;
end HelloWorld;
```

```
>> simulate(HelloWorld)
record SimulationResult
resultFile = "Simulation failed."
end SimulationResult;
```

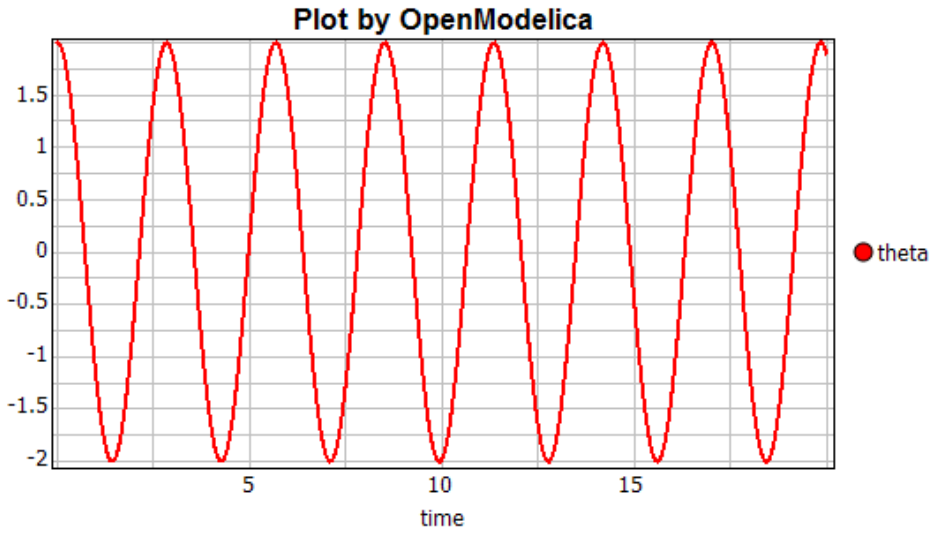
Other Modelica Simulation Environments:

The following error was detected at time: 0

Model error-division by zero: (a*x) / (0) = (1) / (0)

Most important: error messages (2)


```
model Pendel
 Real theta(start=2);
 Real omega;
 parameter Real L=2;
 constant Real g=9.81;
equation
 der(theta) = omega;
 der(omega) = -(g/L)*(theta);
end Pendel;
```




```
model Pendel
 Real theta(start=2);
 Real omega;
 parameter Real L=2;
 constant Real g=9.81;
equation
 der(theta) = omega;
 der(omega) = -(g/0)*(theta);
end Pendel;
```

```
>> simulate(Pendel, stopTime=20)
record SimulationResult
resultFile = "Simulation failed.
Error: Division by zero in 9.81 / 0.0 "
end SimulationResult;
```

Conclusion: Priority of libraries

1. Modelica Standard Library
2. Multi Body Library
3. Modelica_Media
4. Modelica_Fluid
5. Others

But for OpenModelica most important:

→ **Plausible error messages**

MultiBody simulation in MathModelica

Peter Aronsson, *peter.aronsson@mathcore.com*

www.mathcore.com

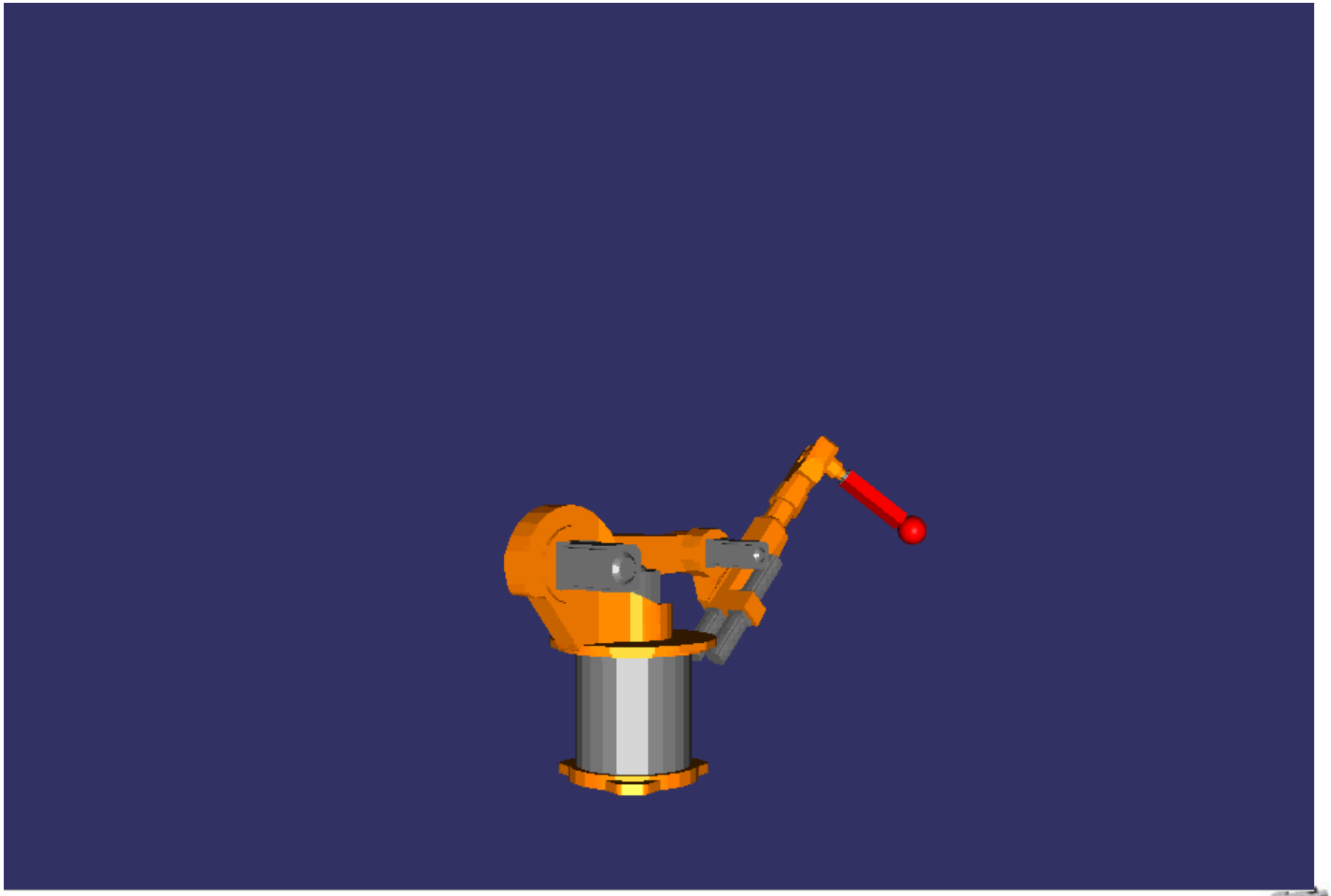
info@mathcore.com

+46 13 32 85 00

Old Multibody library

- MathModelica currently support old version of MultiBody library:
  - Visualization of 3D mechanics
  - Kinematic loops require special consideration in user models
  - Complicated connection rules
  - Non-standardized operator constrain() used.

MathModelica Multibody visualization



New Multibody library

- Main features:
  - About 60 main components (joints, force,part,body, etc)
  - About 75 functions to operate on Orientation object/coordinate systems
  - Builtin animation properties of all components
  - Automatic handling of kinematic loops (using new language constructs: Over constrained connection sets)
  - Automatic state selection using the stateSelect attribute.
  - Analytic solution of a class of special mechanical constructs that leads to nonlinear equation systems.

Requirements on backend of a Modelica translator

- For efficient simulation equation tearing is required. (already available in MathModelica)
- New MultiBody library heavliy relies on Orientation record and functions operating on it. This requires
  - Function inlining (using annotation(inline))
    - Both req. before and after index reduction
  - Derivative information (required for e.g. index reduction)
  - Record constructor expansion & simplification

Requirements cont’

- Dynamic state selection
  - Mostly needed for e.g. ”PointGravity” models.
- Analytic solution of certain nonlinear equations (useful for real time simulations)

Issues in OpenModelica frontend and MathModelica backend

- Multibody introduces lookup of functions through instances
  - Required changes to frontend for handling such lookup
  - Redesign of Modelica function code generation for backend also required.
- Index reduction with differentiation of vector & matrix expressions (was previously not implemented)

Status

- MathModelica backend will soon be able to simulate new MultiBody models
  - Much functionality already in place
    - Tearing
    - Common subexpression elimination
    - Analytic jacobians for nonlinear systems
  - Remaining issues:
    - Index reduction with simplification of vector/matrix expressionss including record constructors.

Next MathModelica release

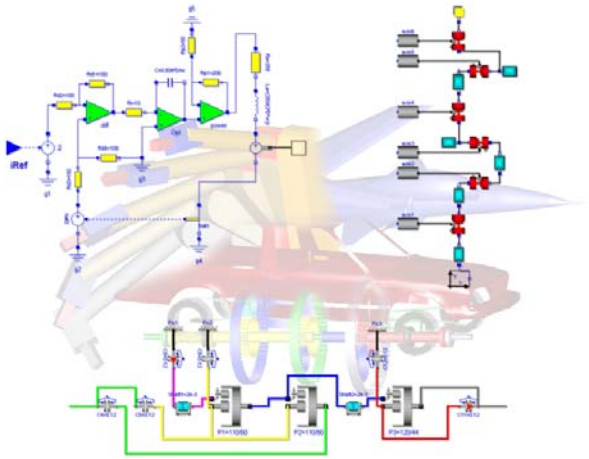
- Support for new MultiBody library
- 3D visualization with custom DXF CAD objects
- Efficient Multibody simulations
- Improved sensitivity analysis
- And much more…

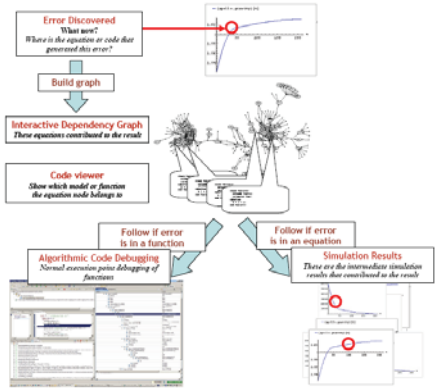
Technical Issues solved in the OpenModelica Compiler to support flattening of the MultiBody library

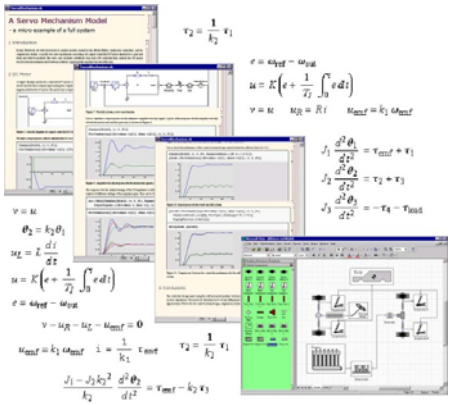
Adrian Pop

2010-02-08

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







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Issues solved to support the MultiBody library

General Modelica issues

- array aliases (100%) (Percentage of implementation work)
- enumerations (95%)
- inner outer with modifications on inner (95%)

MultiBody specific

- calling functions via component i.e. world.gravityAcceleration (100%)
- constraint types (100%)
- breaking of over constrained connection graph (90%)
- performance issues (40%)
- expandable connectors (90%)

Thank You!
Questions?

OpenModelica Project
http://www.OpenModelica.org