KU LEUVEN

THERMAL SYSTEMS SIMULATION

Modelica, Dymola and IDEAS Crash Course 2022

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Who are we?

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The SySi Team

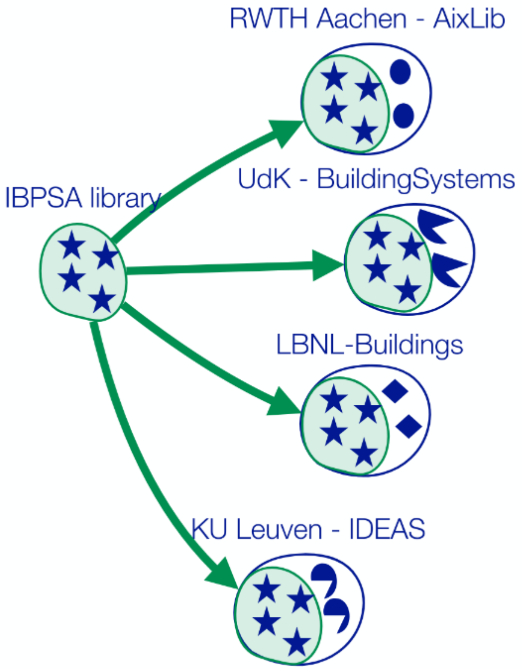
- Led by Professor Lieve Helsen
- Our Mission

  To sustainably use resources through integration and optimization of thermal systems performance in the built environment, including other energy vectors and sectors.

Motivation

- Why a crash course?
  - Introduction for our students and others who are interested in Modelica
  - Broaden the user base

- About IDEAS
  - Modelica users and library development since 2010
  - IDEAS v3.0, BaseClasses inherited from IBPSA project 1
    - https://github.com/open-ideas/IDEAS
    - https://github.com/ibpsa/modelica-ibpsa
  - Many models are validated in academic research
  - Main user base: researchers, students



- Builtwins: spin-off for sustainable control of buildings, using IDEAS

Agenda

Morning: Dymola and Modelica

- 9:30 - 10:00 Lecture 1
  - What is Modelica? What is Dymola? What is OpenModelica?
  - Modelica/Dymola basics
- 10:00 - 10:30 Exercise 1
- 10:30 - 10:45 Break
- 10:45 - 11:30 Lecture 2
  - Create new models/packages
  - Modelling with several components
  - Use connectors
  - Set parameters/propagate parameters
- 11:30 - 12:30 Exercise 2
- 12:30 - 13:30 Lunch break

Afternoon: IDEAS

- 13:30 - 16:00 Lecture 3 + Exercise 3
  - What is IDEAS?
  - IDEAS workflow
- 16:00 - 16:30 Break
- 16:30 - 18:00 Lecture 4 + Exercise 4
  - Hydronic models
  - Discrete control logic

Part 1: Introduction to Modelica and Dymola

Javier Arroyo

Modelica

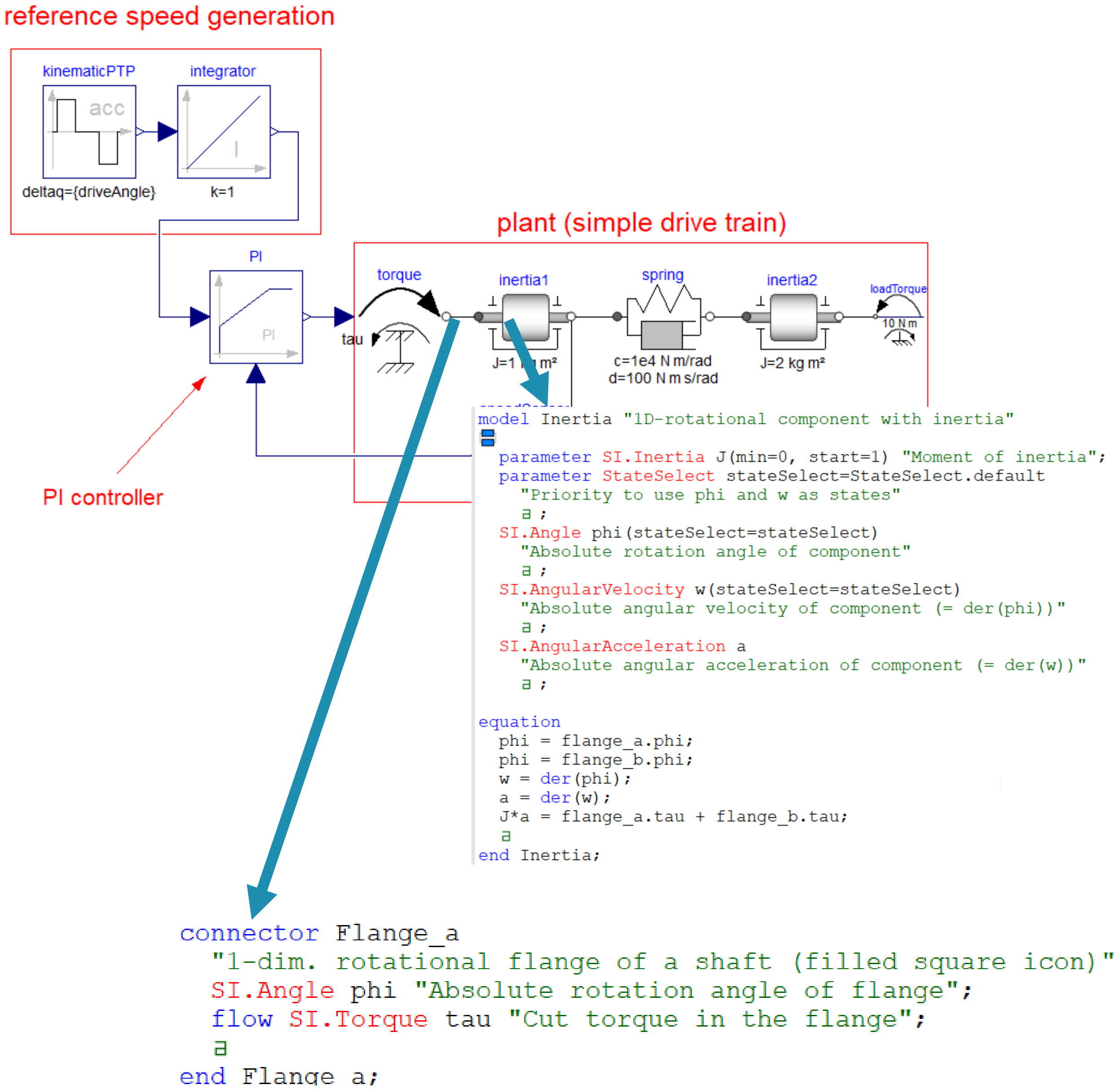
Modelica is a **modelling language** for modelling physical systems

- Language specification is open source
- object oriented
- Acausal modeling (equation-based)
- Multi-domain
- Primarily for simulation, but usable for optimization
- Small and large models (> 100 000 equations)
- Large community with many model libraries, especially in automotive industry (free and commercial)
- Textual and graphical modelling

Modelica

Object-oriented physical equation-based modelling

- A model represents a physical component
- Component is composed of sub-components and/or is described by equations
  → hierarchical structure
- Components can be connected to each other using connectors (=physical coupling)
- To simulate Modelica models, a Modelica simulation environment is needed



```
model Inertia "1D-rotational component with inertia"

  parameter SI.Inertia J(min=0, start=1) "Moment of inertia";
  parameter StateSelect stateSelect=StateSelect.default
    "Priority to use phi and w as states"
    ə ;
  SI.Angle phi(stateSelect=stateSelect)
    "Absolute rotation angle of component"
    ə ;
  SI.AngularVelocity w(stateSelect=stateSelect)
    "Absolute angular velocity of component (= der(phi))"
    ə ;
  SI.AngularAcceleration a
    "Absolute angular acceleration of component (= der(w))"
    ə ;

equation
  phi = flange_a.phi;
  phi = flange_b.phi;
  w = der(phi);
  a = der(w);
  J*a = flange_a.tau + flange_b.tau;
  ə
end Inertia;
```

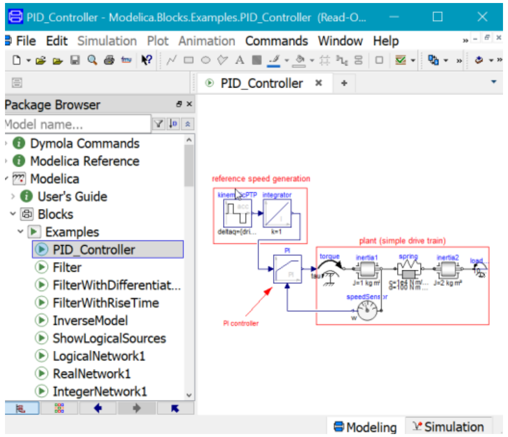
```
connector Flange_a
  "1-dim. rotational flange of a shaft (filled square icon)"
  SI.Angle phi "Absolute rotation angle of flange";
  flow SI.Torque tau "Cut torque in the flange";
  ə
end Flange_a;
```

Dymola

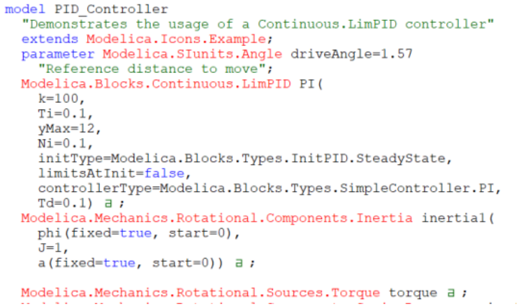
Dymola is a **commercial Modelica simulation environment**

Live demo of features:

- Icon, Diagram, Editor, Info
- Package browser, modelling, simulation
- Set up (compiler), run
- Adapt parameter
- Load libraries
- Look at simulation results: plot, zoom, filter variable, plot as a function of other variable.
- Try Simulate and plot (IDEAS library)
- Open sub-components
- Documentation



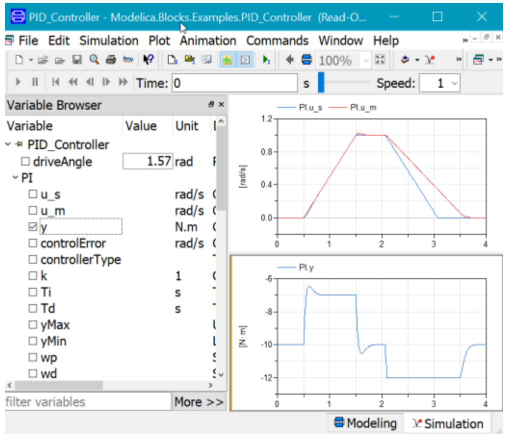
- Graphical editor
- Modelica simulation environment



```
model PID_Controller
  "Demonstrates the usage of a Continuous.LimPID controller"
  extends Modelica.Icons.Example;
  parameter Modelica.SIunits.Angle driveAngle=1.57
    "Reference distance to move";
  Modelica.Blocks.Continuous.LimPID PI(
    k=100,
    Ti=0.1,
    yMax=12,
    Ni=0.1,
    initType=Modelica.Blocks.Types.InitPID.SteadyState,
    limitsAtInit=false,
    controllerType=Modelica.Blocks.Types.SimpleController.PI,
    Td=0.1) a ;
  Modelica.Mechanics.Rotational.Components.Inertia inertial(
    phi(fixed=true, start=0),
    J=1,
    a(fixed=true, start=0)) a ;

  Modelica.Mechanics.Rotational.Sources.Torque torque a ;
```

- Textual description (Modelica language)

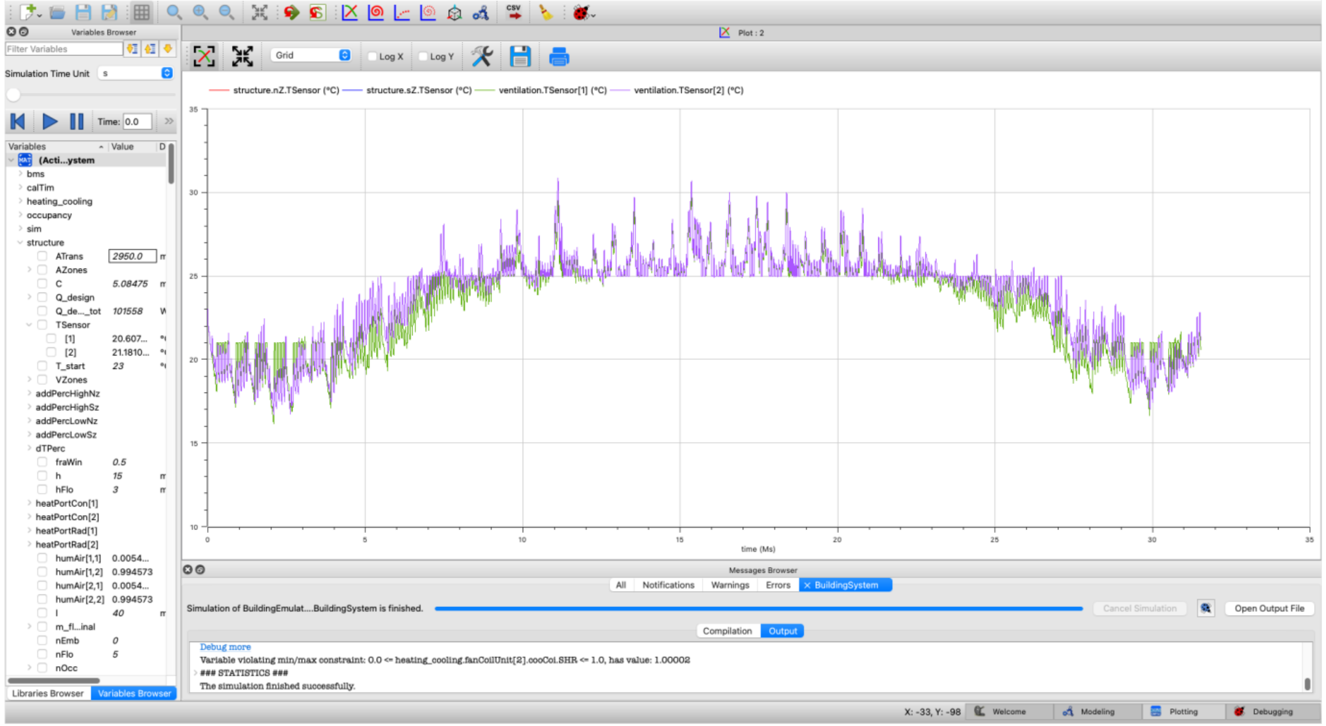


- Translation of Modelica code into executable C-code
- Coupling with a solver
- Visualization of results

OpenModelica

OM is a **free Modelica simulation environment**

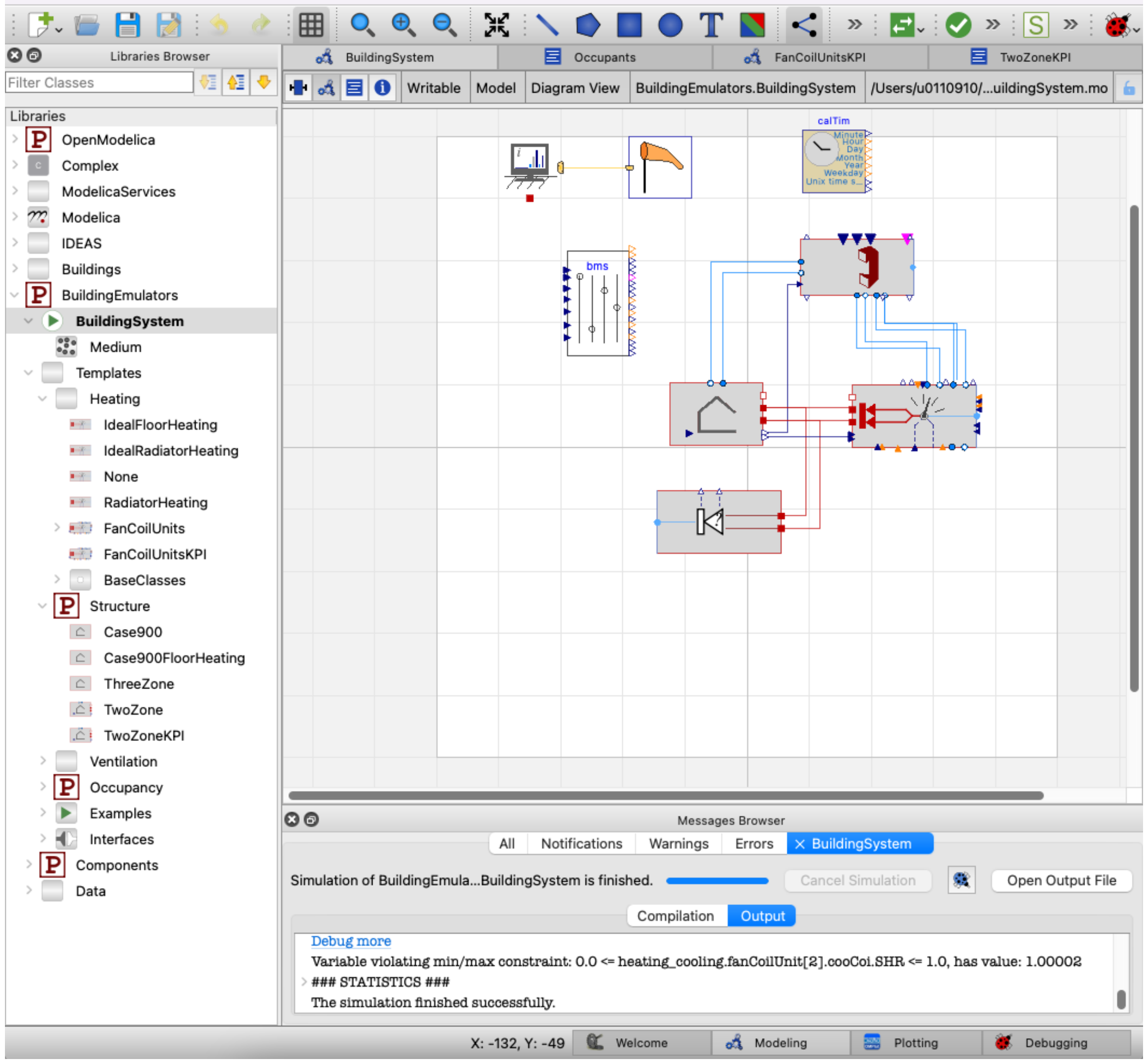
Has very similar features than Dymola, like those we have just seen



Variables	Value
(Acti...ystem	
bms	
calTim	
heating_cooling	
occupancy	
sim	
structure	
ATrans	2950.0
AZones	
C	5.08475
Q_design	
Q_de..._tot	101558
TSensor	
[1]	20.607...
[2]	21.1810...
T_start	23
VZones	
addPercHighNz	
addPercHighSz	
addPercLowNz	
addPercLowSz	
dTPerc	
fraWin	0.5
h	15
hFlo	3
heatPortCon[1]	
heatPortCon[2]	
heatPortRad[1]	
heatPortRad[2]	
humAir[1,1]	0.0054...
humAir[1,2]	0.994573
humAir[2,1]	0.0054...
humAir[2,2]	0.994573
l	40
m_fl...inal	
nEmb	0
nFlo	5
nOcc	

Simulation of BuildingEmulat....BuildingSystem is finished.

```
Debug more
Variable violating min/max constraint: 0.0 <= heating_cooling.fanCoilUnit[2].cooCoi.SHR <= 1.0, has value: 1.00002
### STATISTICS ###
The simulation finished successfully.
```



Simulation of BuildingEmula...BuildingSystem is finished.

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Debug more
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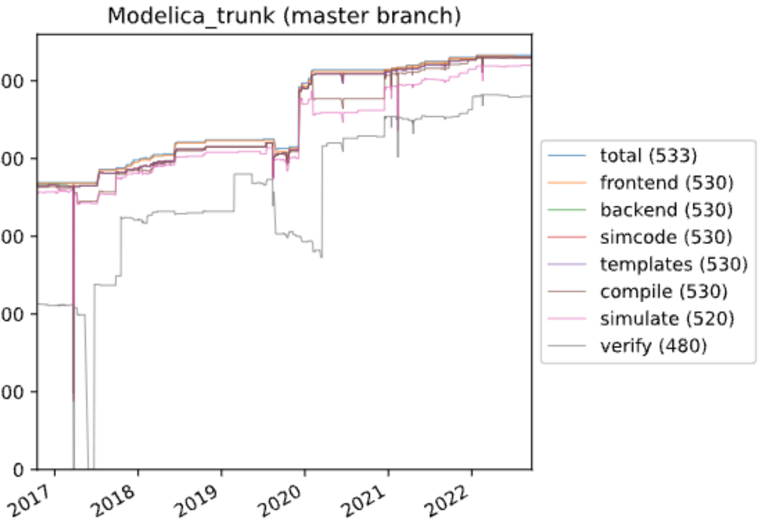
### STATISTICS ###
The simulation finished successfully.
```

OpenModelica

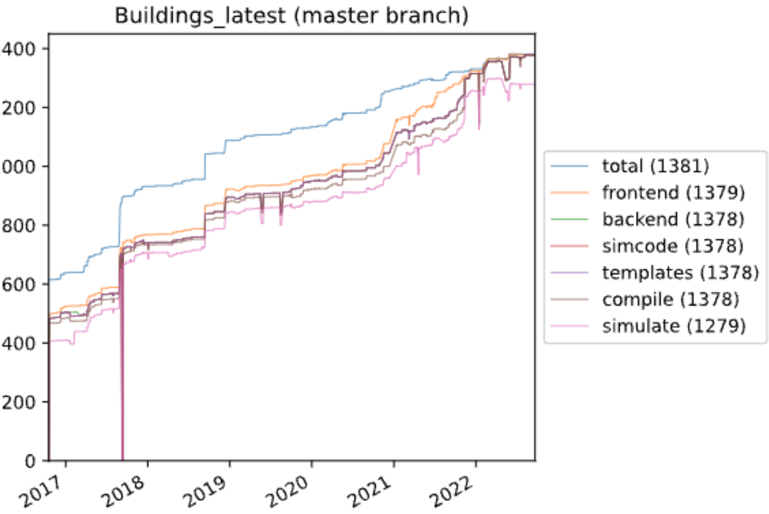
Historically less performant than Dymola, but has radically improved over the last years:

Modelica Standard Library (MSL) coverage



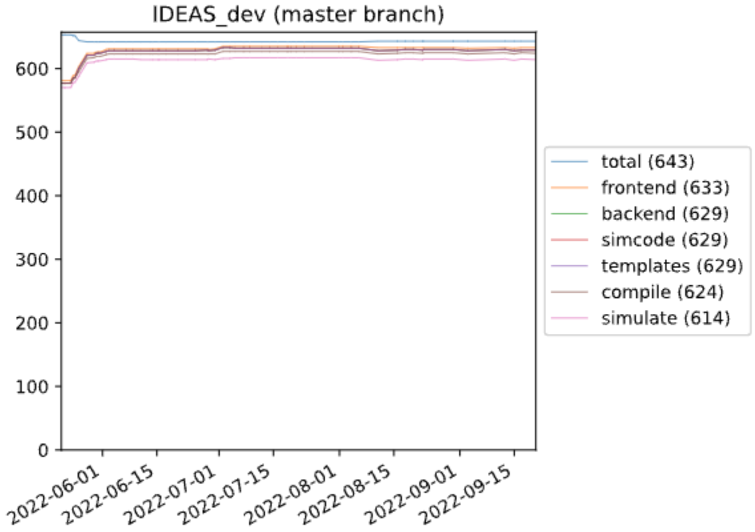
https://libraries.openmodelica.org/branches/history/master/Modelica_trunk.svg

Buildings library coverage



https://libraries.openmodelica.org/branches/history/master/Buildings_latest.svg

IDEAS coverage (recently added!)



https://libraries.openmodelica.org/branches/history/master/IDEAS_dev.svg

The only reason not to use it this year: still lacks a few graphical features. OM team is working on them

Useful links

General

- www.modelica.org
- www.openmodelica.org
- www.jmodelica.org DISCONTINUED
- http://www.claytex.com/tech-blog/

Modelica language

- http://book.xogeny.com/
- http://doc.modelica.org
- http://specification.modelica.org/

Libraries:

- IDEAS
  https://github.com/open-ideas
- Buildings
  https://simulationresearch.lbl.gov/modelica
  (look at Buildings.Examples.Tutorial)
- IBPSA Project 1
  https://github.com/ibpsa/modelica-ibpsa

Dymola user guide

- Online
- Via Dymola > help

Exercise 1

- See exercise sheet on Github
  https://github.com/open-ideas/__CrashCourse__/blob/master/Exercises/Exercise%201/Latex/Exercise1.pdf

Part 2: Modelling and simulating in Dymola

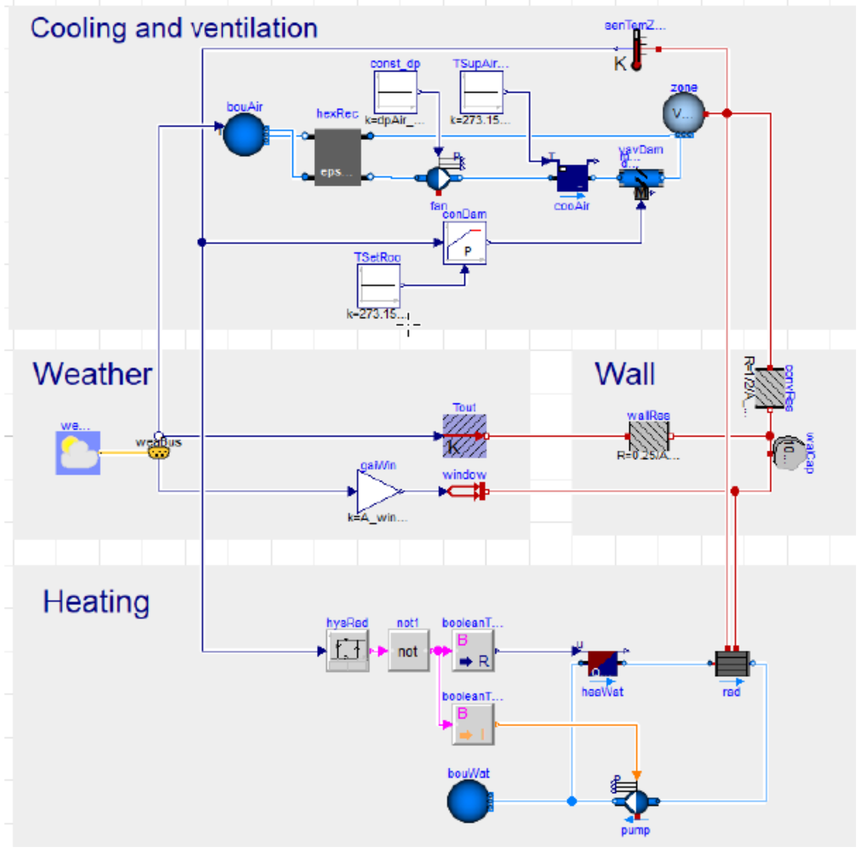
Jelger Jansen

Live demonstration

- Create package, create model
- Units
- Search, drag and drop subcomponents. Instantiate model convention
- Simulation tab and adapt parameters
- Connect components
- Propagate parameters
- Use check/translate in Dymola and debug:
    - Syntax error
    - Modeling error: singularity
    - Model with external input
- Saving and exporting results as .csv, .mat, .txt
- Simulation log/Statistics

Exercise 2: Simple house model

- See exercise sheet on Github
  https://github.com/open-ideas/__CrashCourse__/blob/master/Exercises/Exercise%202/Latex/Exercise2.pdf


Cooling and ventilation
senTemZ...
K
const_dp
k=dpAir_...
TSupAir...
k=273.15...
zone
V...
bouAir
hexRec
eps...
fan
cooAir
vavDam
conDam
P
TSetRoo
k=273.15...
Weather
we...
weaBus
Tout
K
gaiWin
k=A_win...
window
Wall
walRes
R=0.25/A...
R=1/2/A...
convRes
walCap
Heating
hysRad
not1
not
booleanT...
B
R
booleanT...
B
I
heaWat
rad
bouWat
pump