## Use of Modelica Libraries and OpenModelica at Politecnico di Milano

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## Outline

- Uses of Modelica at Politecnico di Milano DEI
  - Modelling and simulation for control system design
    - Power plants and energy system
    - Robotics and mechatronics
    - Vehicle dynamics, 2- and 4-wheels
    - Home appliances
    - Satellite systems
  - Research on algorithms and tools
    - Direct generation of models for control system design
    - Nonlinear model order reduction
    - Parallel simulation
    - Development of a GUI, including IEC 61131 languages for industrial controllers
  - Teaching
- Current situation with Modelica libraries and tools
- Perspectives for the future using OMC

### Modelica at Politecnico - DEI

- Interest in equation-based, O-O modelling for CACSD since 1994, pioneered by prof. Claudio Maffezzoni
- MOSES environment (1996), based on an O-O database
- Using Modelica and Dymola since 2000
- Actively involved in the Modelica Association since 2004
- Actively involved in the OSMC since 2008
- Wide range of system-level, control-motivated applications
- Emerging research activity on methodological issues
- Teaching and promotion of O-O modelling culture

## **Power Plants and Energy Systems**

- Modelica used for power plant and energy system modelling since 2002
- Medium to Large size model
  - Steam generators
  - Combined-cycle power plants
  - Flue gas path control systems for coal plants
  - Gasification plants
  - Innovative PWR nuclear plants
  - Organic Rankine Cycle plants
  - Cryogenic systems
- ThermoPower library developed at DEI
  - Main use: analysis and validation of control system strategies
  - Stiff, coupled, large-sized nonlinear models
- Modelica.Media essential for fluid property modelling



## **Robotics and Mechatronics**

Integrated mechanical and control system design for machining tools Innovative control system design for robots impedance control flexible robots Frame\_b1 - 7 d.o.f. manipulator parallel kinematics manipulators Erame b2 Real-time simulators with haptic 13 Frame\_b3 interfaces Frame\_a MultiBody library needed as basic building block Much interest on automatic code generation for real-time control Inverse kinematics Inverse dynamics **Jacobians** 

# **Vehicle Dynamics**

- Support to control system design for active braking, active suspension, and powertrain control
- Special emphasis on motorcycles, including advanced concepts (two front wheels, quad-wheel motorcycles)
- Mainly used in simulation for validation of control strategies
- MultiBody library needed as basic building block





## Home Appliances

- Support to the design of control and diagnostic systems for home appliances
- Washing machines: speed control, load unbalance monitoring
- Dryers: comprehensive modelling for enhanced control
- Refrigerators: analysis of innovative control strategies
- Use of MultiBody for 3D mechanical models
- Use of ThermoPower and Modelica.Media for thermo-hydraulic models





## **Satellite Systems**

- Comprehensive support of mission design w.r.t. attitude and orbital control
  - actuator sizing and configuration
  - control system validation by simulation
- Development of the SpacecraftDynamics library
  - state-of-the-art modelling of the space environment
  - flexible modelling framework based on replaceable models
- Based on MultiBody library for rigid-body satellite dynamics



# Teaching

- 50-hours course at the master's level on tools and methods for system simulation, including hands-on lab activity
- 20-hours PhD course on fundamentals and applications of O-O modelling (every two years)
- Reference to Modelica in other courses (e.g. Control Systems Engineering and Modelling and Control of Continuous Processes)

#### **Research on tools and methods**

- Tool integration based on XML
- Generation of models for direct control system design (e.g. LFR)
- Model order reduction
- Parallel simulation
- Open source GUI using OMC (SimForge)





## **Tools used at Politecnico: current status**

- All applications developed using Dymola
  - Use of Modelica.Media and MultiBody library
  - Some quite large models (but not all!)
- All tool-related research done with OMC
  - Opennes of the tool is a key requirement
- Issues with Dymola (or any other proprietary tool!)
  - Tool requires licensing (money + management chores)
  - Code generated by the tool require licensing (!)
  - Closed-source: not good for tool-related research
  - Neutral tool preferred for teaching O-O concepts and Modelica
  - Acceptance by industrial partners (typically using Simulink)
  - Probably unnecessarily powerful for many tasks



### **Current issues with OpenModelica**

- Modelica.Media and Modelica.Mechanics.Multibody are not supported by OMC 1.4.5
- Numerical efficiency of back-end should be improved (in particular w.r.t. tearing and initialization)
- Diagnostics of numerical problems should be improved and made more user-friendly

### **Future Perspectives - I**

- Modelica.Media and Modelica.Mechanics.MultiBody will be supported by the front-end from Jul 2009
- All applications will (at least in principle) be compatible with OMC

# Will OMC 1.5 be good enough?

- Most applications of interest at Politecnico are reasonably sized
  - 10-100 state variables after index reduction
  - 100-1000 algebraic variables after alias elimination
- It is expected that at least some could be moved to OMC by the end of the year 2009

### **Future Perspectives - II**

- Teaching activities could be supported 100% by OMC + SimForge
- All models will be immediately available for advanced uses
  - direct generation of models suitable for CS design
  - model order reduction
  - parallel simulation
  - ...
- Modelica could become more attractive for research and consulting work with 3<sup>rd</sup> parties
  - typically using Simulink
  - reluctant to invest money in alternative proprietary tools
  - might just need to use models in compiled form with no licensing fees
- Uses other than simulation might become feasible
  - Inverse kinematics, inverse dynamics, Jacobians for robotic applications
  - Fast models for MPC obtained through inline integration
  - LFT models for identification and control

### **Critical issues**

- Stable front-end with good diagnostics in case of modelling errors
- Improved back-end for small- and mid-sized models
  - tearing (crucial for thermo-fluid applications)
  - improved diagnostics and user feed-back for nonlinear solver errors
  - improved initialization (expecially for steady-state initialization problems)
- Open and standard interfaces for model export to other tools (MODELISAR effort!)
  - Simulink
  - Scicos
  - LabView
  - ...
- Improved SimForge GUI

## Conclusions

- Modelica has been used at Politecnico since 2000, for a wide range of applications, using Dymola
- Started working on OMC in 2008, for research on tools and methods
- Little use so far due to lack of support of Media and MultiBody libraries, used in most applications
- Progress in 2009 might bring **revolutionary** change
- Huge potential for many application fields, and also for non-simulation use
- Back-end strenghtening and model export features
  crucial for success