OtFMI, an OpenTURNS module for uncertainties analysis with 0D/1D system models

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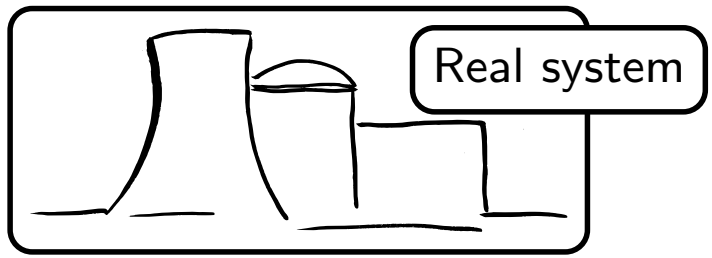
Industrial issue

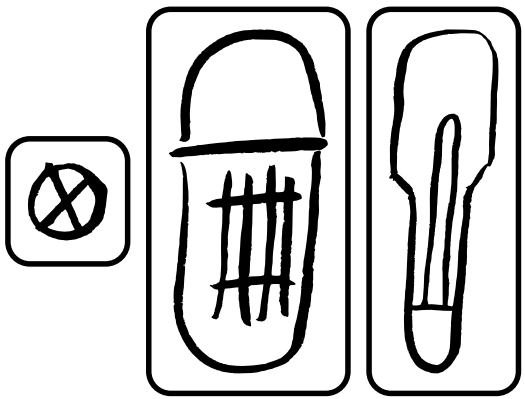
- EDF uses 0D/1D system models programmed in Modelica as decision support for the conception and operation of its industrial assets.

- How to apply OpenTURNS' panoply of methods to these models?

"Regular" models *vs* 0D/1D system models

"Regular" modelling





"Packing"

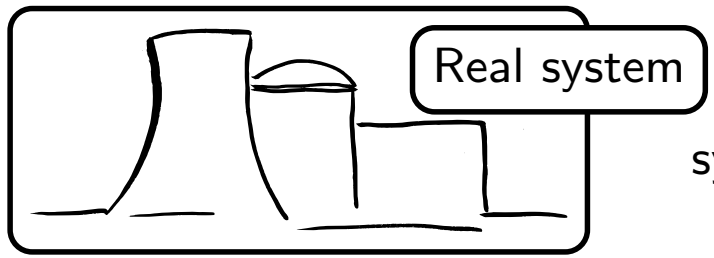
$$\begin{cases} \dot{\boldsymbol{x}}(t) = f\left(\boldsymbol{x}(t), \boldsymbol{u}(t), t\right) \\ \boldsymbol{y}(t) = g\left(\boldsymbol{x}(t), \boldsymbol{u}(t), t\right) \end{cases}$$

Equation formulation

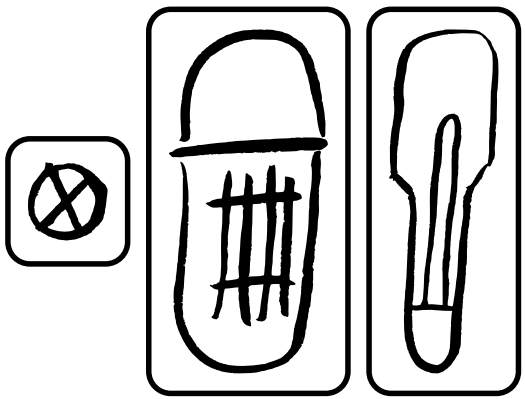
Solver programming

"Regular" models *vs* 0D/1D system models

"Regular" modelling



0D/1D system modelling



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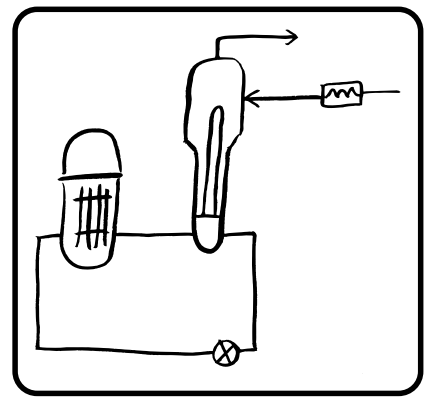

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Equation formulation

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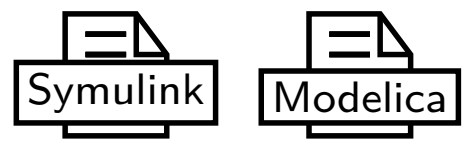
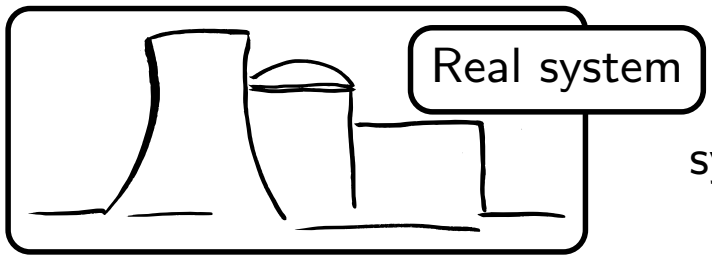
Solver programming



"Regular" models *vs* 0D/1D system models

"Regular" modelling		0D/1D system modelling
		
Long (minute → hour)	CPU time	Short (second → minute)
2D, 3D	Dimensions	0D, 1D
Discrete versioning	Development rate	Continuous mutation
Numerical analyst, physicist	Actors	Design, process, operation... engineer
CFD, finite elements, C++, FORTRAN...	Tools	Modelica, Simulink...

Modelica programming language

- Modelica is an open language for programming models based on differential algebraic systems of equations

- Equations are written in almost natural language, and solved by a multipurpose third party tool.

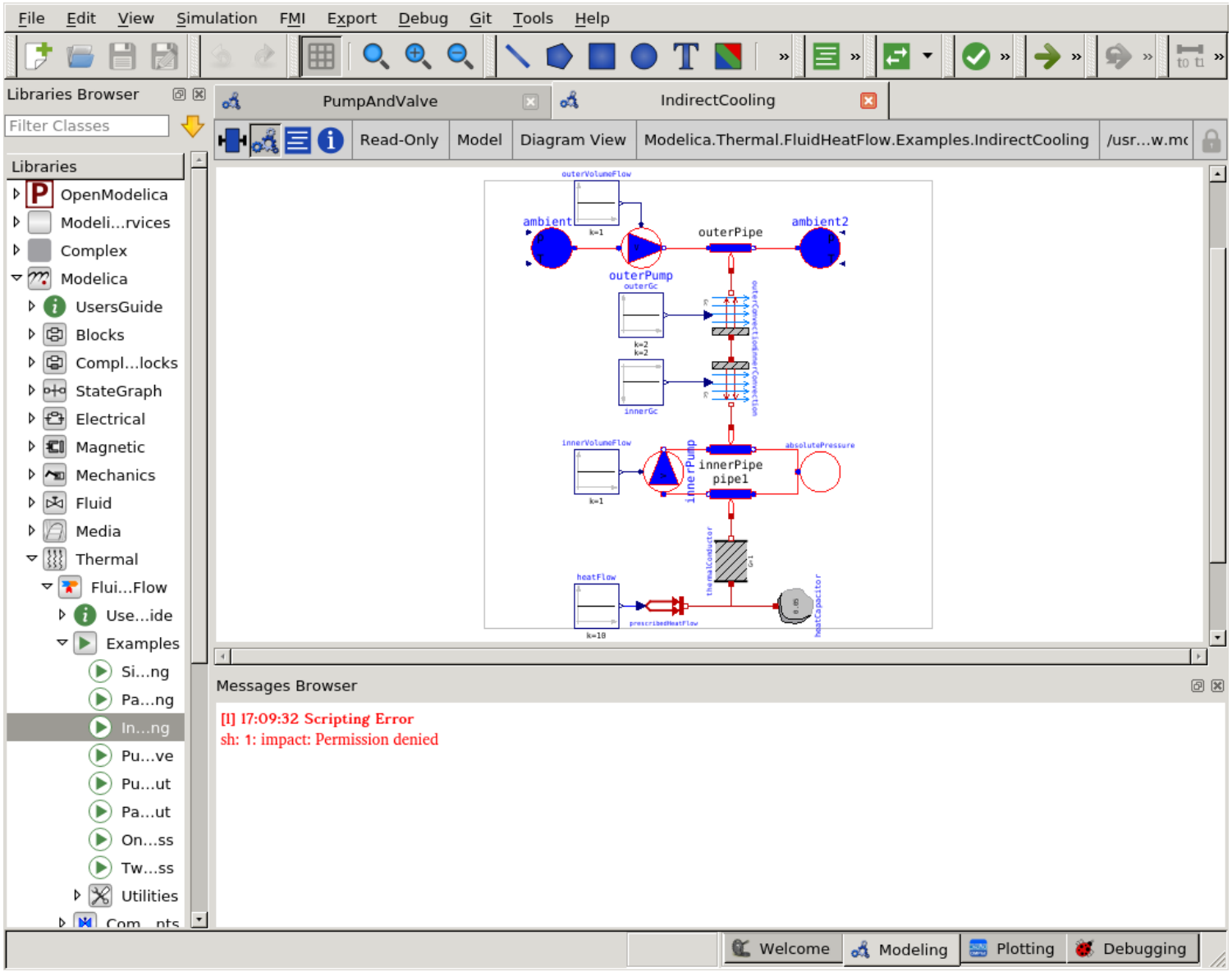
- It is object-oriented: available module libraries cover most applications
  - Complex models can be achieved simply by combining this modules using a graphical interface!

Modelica tools

- Main tools :
  - Dymola (Dassault Systèmes, proprietary)
  - OpenModelica (Open Source Modelica Consortium, open source)

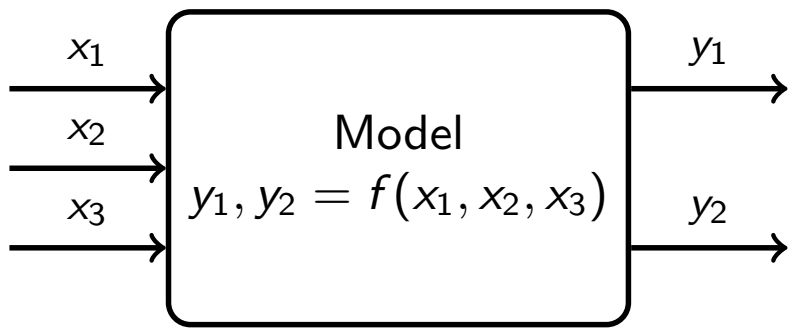
- Functions
  - Flatten equation systems
  - Compile to machine code after including a solver
  - Development environment
  - Model graphical interface
  - Basic post-processing...

OpenModelica, model graphical view



Piloting models

- Most OpenTURNS methods apply to functional black boxes
  - Uncertainty propagation and reliability analysis
  - Sensitivity analysis
  - Emulation
  - Parameter estimation

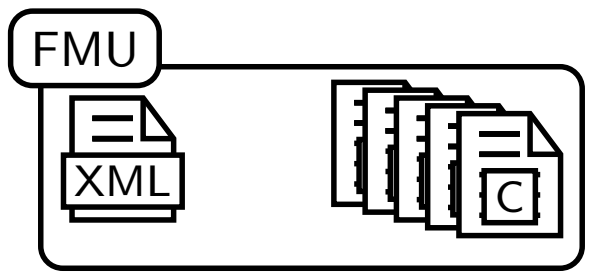


- We need efficient input–output data interfaces, a.k.a. *wrappers* in OpenTURNS jargon.

Functional mock-up interface (FMI)

- FMI is a standard for input–output data interface for numerical model.

- A functional mock-up unit (FMU) is a black box following the standard.



https://www.fmi-standard.org/

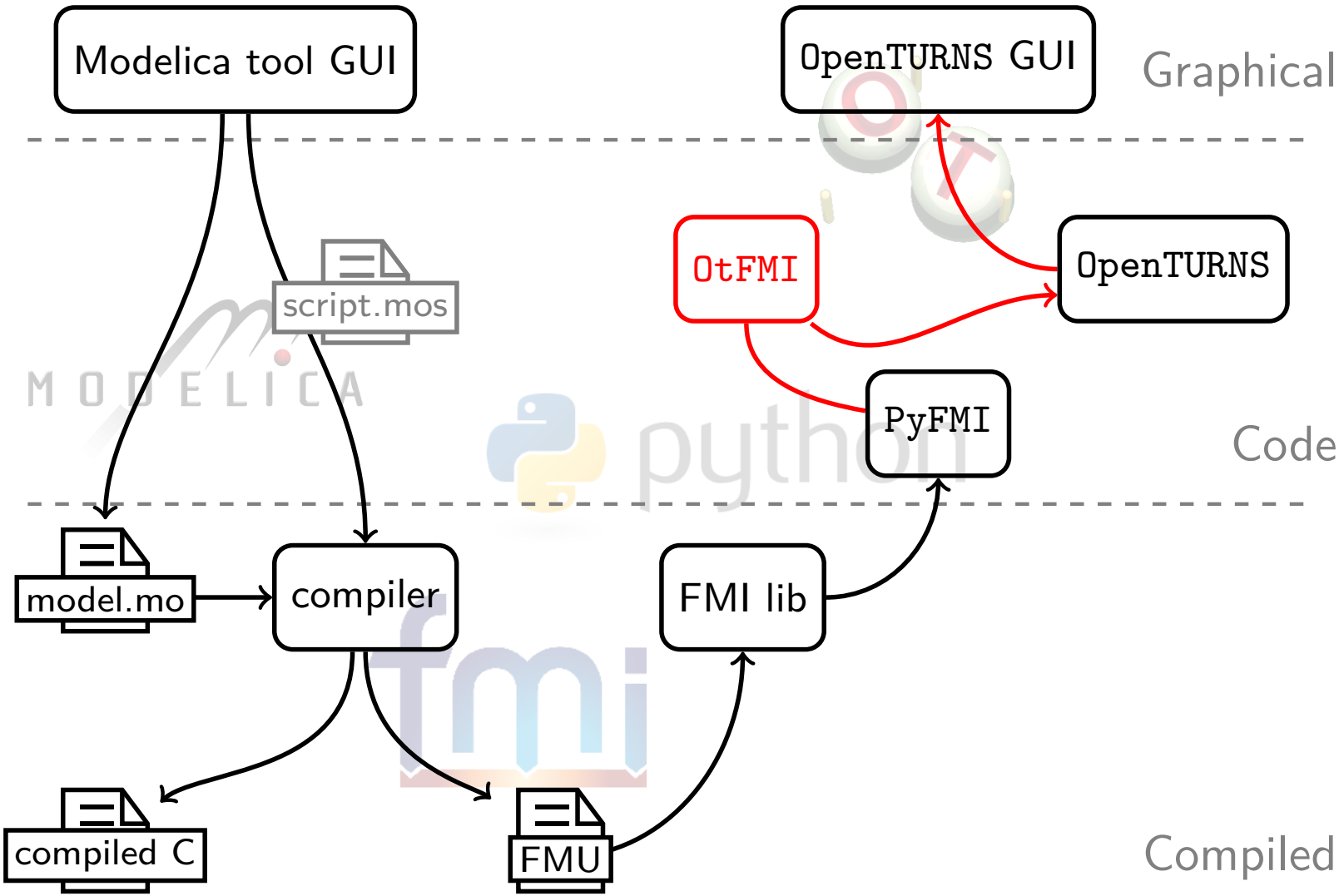
OtFMI: integrating FMI support into OpenTURNS

- The new open source module OtFMI allows transparent use of FMU with OpenTURNS methods.

- It provides high level classes derived from ot.PythonFunction: running an FMU instead of a Python function only requires to change a single code line!

```
import otfmi
otfmi.FMUFunction("path/to/fmu",
                  inputs_fmu=["x_1", "x_2", "x_3"],
                  outputs_fmu=["y"])
```

Implementation overview



OtFMI grahical interface

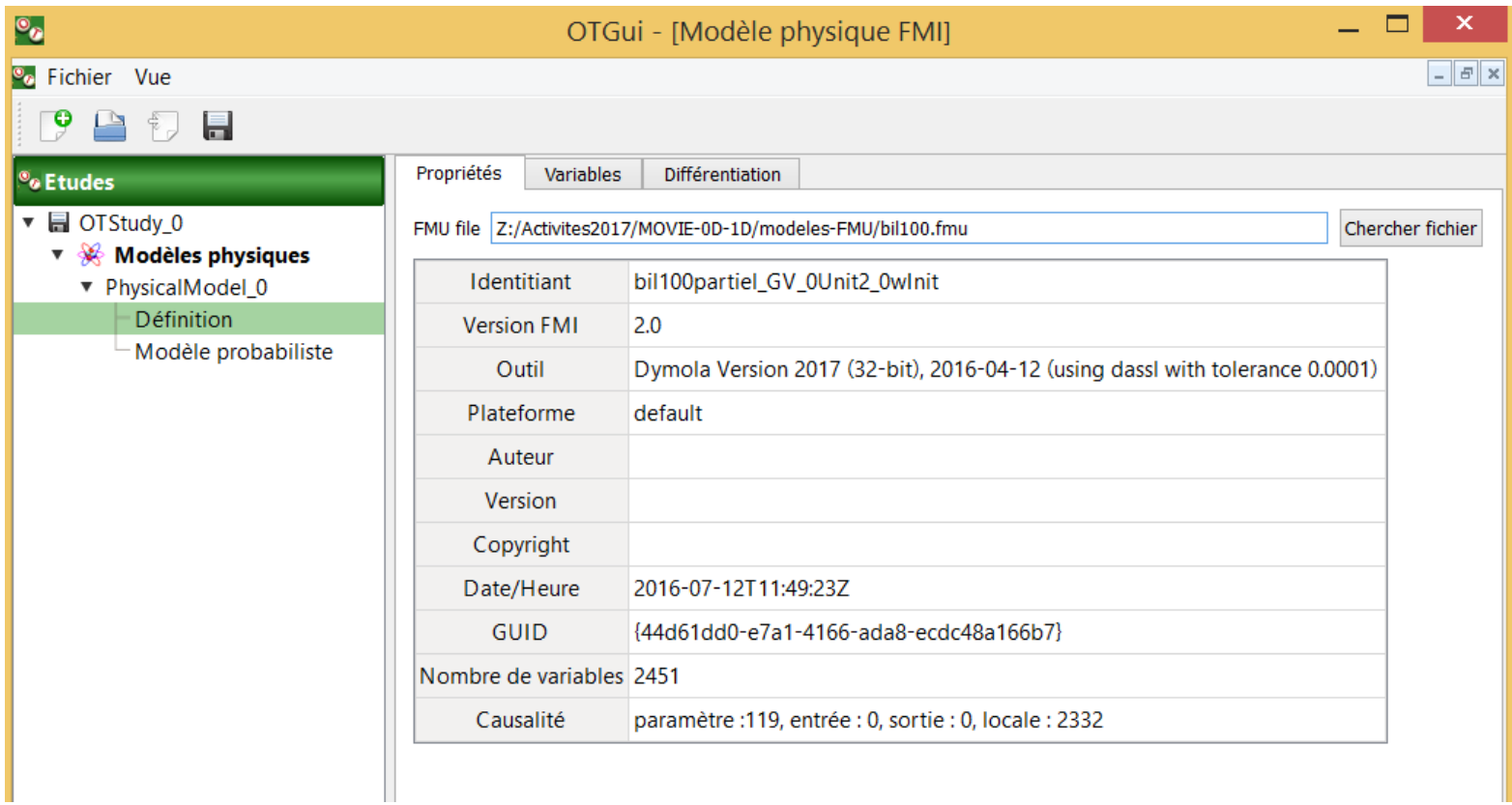
Motivations

- Provide access to OpenTURNS' methods for Modelica users unfamiliar with Python
- Considerably ease simple studies

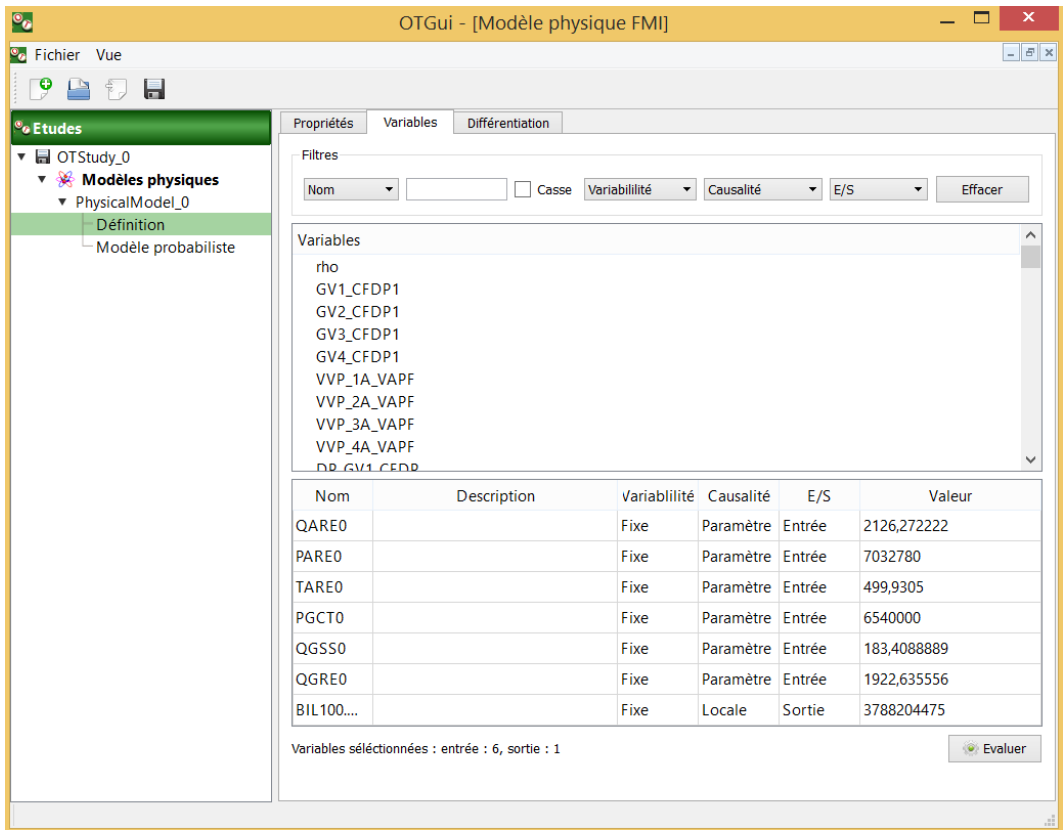
Issues

- Modelica models often define hundreds or thousands of variables

OtFMI grahical interface, FMU overview



OtFMI grahical interface, picking inputs and outputs



Perspectives

- Most 0D/1D system model are dynamical.
  We need methods for sensitivity analysis and emulation of model with time series inputs or outputs.

- EDF is interested into data assimilation with its Modelica models.

- What are the opportunities of extending the Modelica language to support stochastic description of variables?

Thank you for your attention.