# Model-Based Dynamic Optimization with OpenModelica and CasADi

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# Outline of Presentation

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# Motivation

- **Modelica** enable users to conveniently model large-scale physical systems
  - Traditionally used for simulation
- Nonlinear optimal control problems (NOCP) based on differential-algebraic equations (DAE)
  - State-of-the-art methods are using numerical algorithms
- Many other possible usages of the model
  - For example dynamic optimization for NOCP
- Current Modelica tools mainly focused on simulation, but recently also optimization
  - Dymola supports parameter and design optimization of models written in Modelica whereas
  - JModelica.org and OpenModelica have native support for optimal control.

# Optimization with Modelica

- Modelica has strong support for modeling of dynamic systems
- Additional elements for optimization:
  - Cost function
  - What to optimize (Variables and Parameters) and
  - Constraints
- Optimica language extension:
  - Extension of Modelica.
  - Enables formulation of optimization problems in Modelica models.
- How ?
  - Export Models in XML from OpenModelica and Import to CasADi

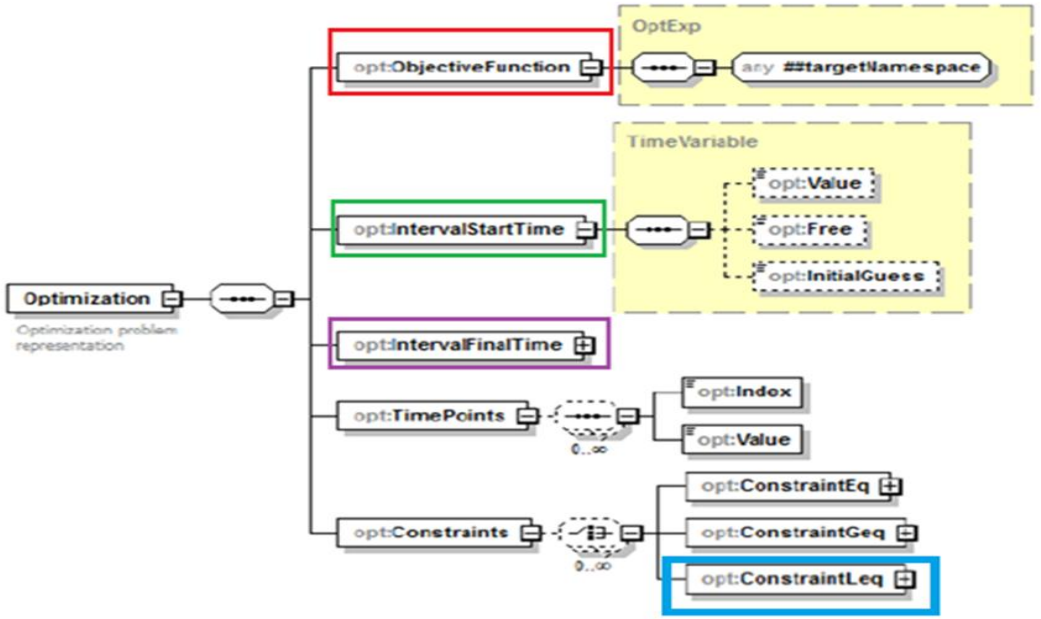
# OpenModelica and CasADi

- OpenModelica
  - Modelica-based modeling and simulation platform
  - Support optimica extension
  - Extended with XML export of models based on standardized XML schema for models
  - The XML export also includes the Optimica extension
- CasADi
  - An open-source framework for numerical optimization developed by *KU Leuven*
  - Enable users to implement optimal control algorithms with a wide range of methods, including
    - Multiple shooting and
    - Collocation
  - Imports XML for dynamic optimization

# XML Code Generation in OpenModelica

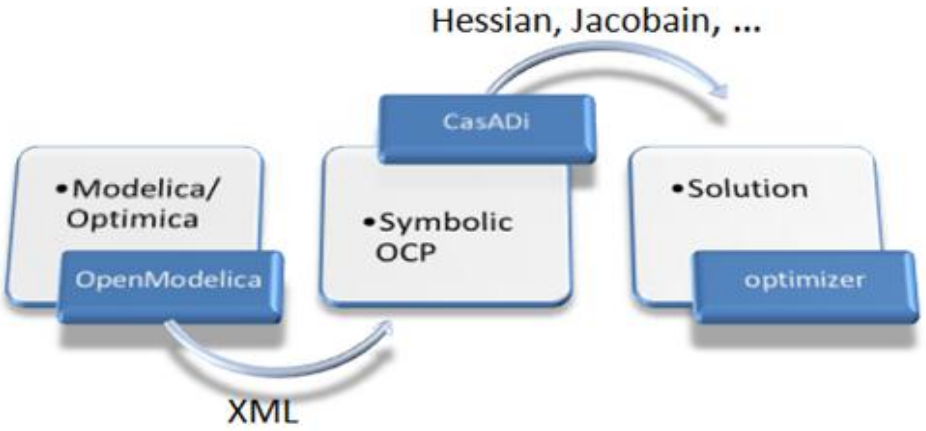
- Modelica models are first flattened.
- XML schema structure mapped to the abstract syntax tree of OpenModelica compiler
- Text template based implementation of the code generation to XML

```
optimization VDP_Opt (objective = cost(finalTime),
                      startTime = 0, finalTime = 20)
  parameter Real p1 = 1;
  parameter Real p2 = 1;
  parameter Real p3 = 2;

  Real x1(start = 0);
  Real x2(start = 1);

  input Real u;

  Real cost(start=0);

equation
  der(x1) = (1 - x2 ^ 2) * x1 - x2 + u;
  der(x2) = p1 * x1;
  der(cost)=exp(p3*1/*time*/) * (x1^2 + x2^2 + u^2);

  constraint    u<=0.75;

end VDP_Opt;
```



# Optimization Tool Chain for OpenModelica and CasADi

- **Export** of model from OpenModelica platform
- **Import** the model in CasADi
- **Solve** optimization problem in CasADi

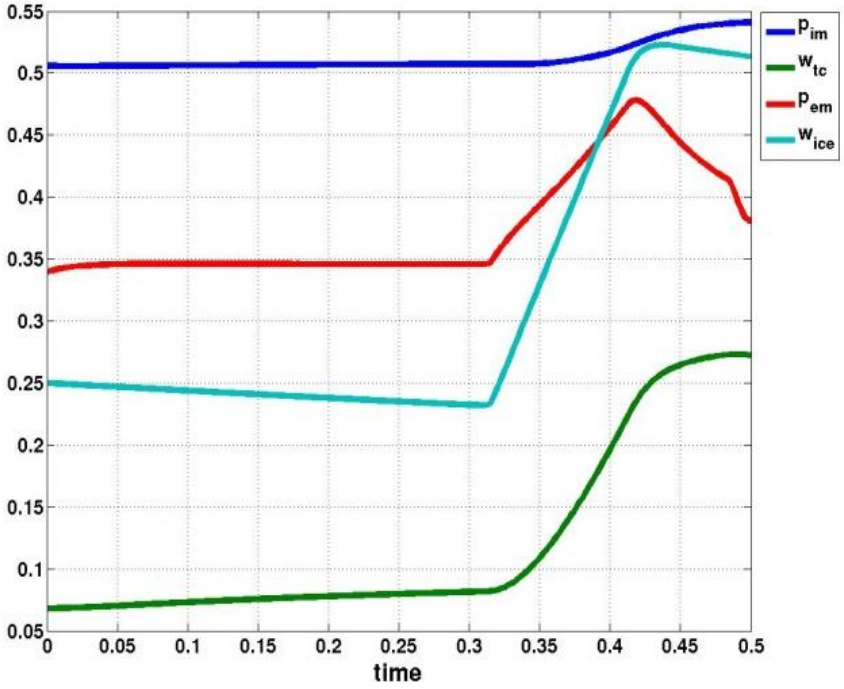


# Test Cases - Diesel Electric Powertrain

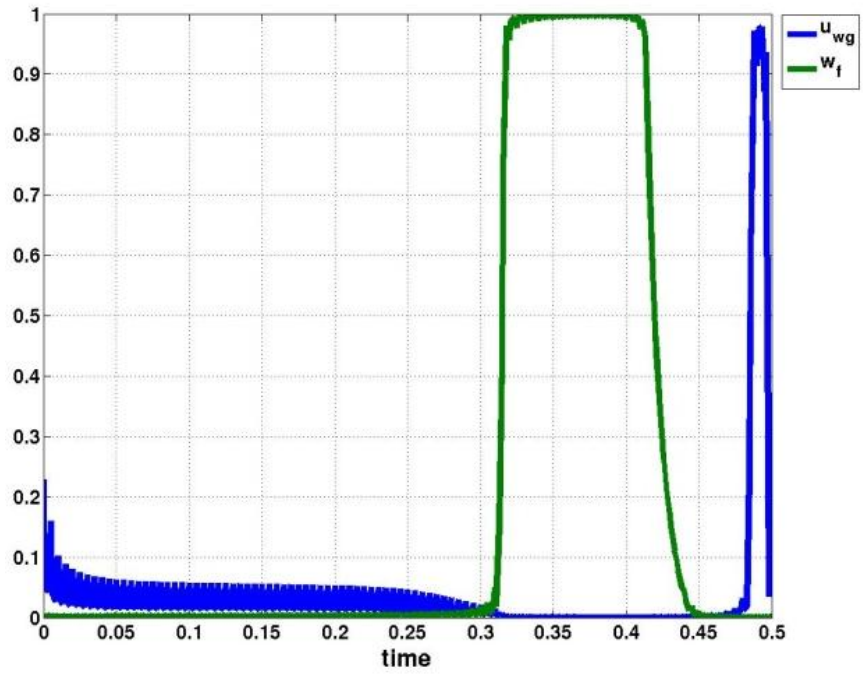
- Presented by
  - **Martin Sivertsson** and **Lars Eriksson**. (2012)
  - **Bernhard Bachmann and et al.** (2012).
- Nonlinear mean value engine model (MVEM)
- Find fuel optimal control and state trajectories from idling condition to a certain power level
- Mathematical problem formulation:
  - 2 inputs ($uf$,$uwg$)
  - 4 states ($\omega ice$,$pim$,$pem$,$\omega tc$)
  - 32 algebraic equations
- The problem solved here is a minimum fuel problem for a transient from idle to 170 kW, in a certain time interval [0,0.5].

# Results- Diesel Electric Powertrain

**State variables** $(\omega ice, pim, pem, \omega tc)$




**Control variables** $(uf, uwg)$




- Engine is accelerated only near the end of the time interval to meet the end constraints while minimizing the fuel consumption

# Conclusions

- Model-based dynamic optimization with OpenModelica and CasADi has been demonstrated on three industrial use cases.
- The OpenModelica platform coupling with CasADi demonstrates the use of an XML-based model exchange format for model-based optimization with OpenModelica

# References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# Questions

Thank you !!