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 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
  - 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 ($u_f, u_w$)
  - 4 states ($\omega_{ic}, \rho_{im}, \rho_{em}, \omega_{tc}$)
  - 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

➢ 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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References


Questions

Thank you !!