

Tool Demonstration Abstract: OpenModelica and CasADi for Model-Based Dynamic Optimization

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Abstract

This paper demonstrates model-based dynamic optimization through the coupling of two open source tools: OpenModelica, which is a Modelica-based modeling and simulation platform, and CasADi, a framework for numerical optimization. The coupling uses a standardized XML format for exchange of differential-algebraic equations (DAE) models. OpenModelica supports export of models written in Modelica and the Optimica language extension using this XML format, while CasADi supports import of models represented in this format. This allows users to define optimal control problems (OCP) using Modelica and Optimica specifications, and solve the underlying model formulation using a range of optimization methods, including direct collocation and direct multiple shooting. The proposed solution has been tested on several industrially relevant optimal control problems, including a diesel-electric power train, a free-floating robot, and a stirred-tank.

Keywords Model-Based Optimization, OpenModelica, Dynamic Optimization, Modelica, CasADi

1. Introduction

During the last decade, nonlinear model predictive control (NMPC) and nonlinear optimal control problems (NOCP) based on differential-algebraic equations (DAE) have had a significant impact in the industrial community, particularly in the control engineering area [1, 2]. State-of-the-art methods are using numerical algorithms for dynamic optimization based on direct multiple shooting [3] or collocation algorithms [1].

Equation-based, object-oriented modeling languages such as Modelica [4] have become increasingly used for industrial applications. These languages enable users to conveniently model large-scale physical systems described by differential, algebraic, and discrete equations, primarily with the goal of performing virtual experiments (simulation) on these systems, but recently also optimization.

Due to the influence of such equation-based, object-oriented modeling languages in the industrial community, there have been results of an effort where model-based dynamic optimization has been done by coupling of OpenModelica and CasADi [5], which is a numerical algorithmic tool. The problem formulation and modeling is done in Modelica [6] including the Optimica language extensions described in [7] using the OpenModelica graphical editor (OMEdit) and then export the model and optimization descriptions into an XML format (Figure 1). This enables users to formulate and use model-based NOCP that can be solved by CasADi, see also [12].

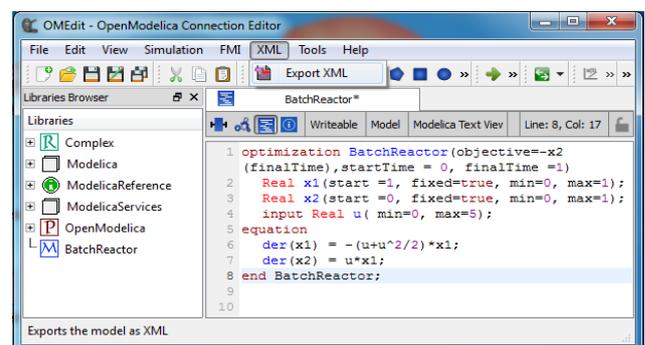


Figure 1: Modeling NOCP using the OpenModelica Graphical and Textual Editor

2. OpenModelica Compiler and CasADi

The OpenModelica compiler front-end has been extended to support the Optimica language extensions. In addition, the OpenModelica compiler has recently been extended with XML export of models [8] based on the XML format

defined in [9], also including the Optimica extensions. In essence, the task of OpenModelica is to read the Modelica and Optimica source code, translate into a flat model description and then export the model and optimization descriptions into an XML format which can be solved by a numerical algorithmic tool.

The exported XML document can then be imported to CasADi tool. The tool supports symbolic import of OCPs via this XML format. This OCP can then be transcribed into a nonlinear programming problem (NLP) using the approach outlined in [10] of Section 5, and solved with one of CasADi's interfaced NLP solvers. The complete tool chain is visualized in Figure 2.

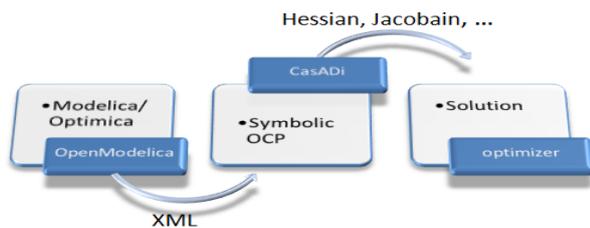


Figure 2: Optimization tool chain for OpenModelica and CasADi

3. Demonstration

In order to present the proposed concept, we demonstrate the solution of an industrial-relevant optimal control problem of diesel engine model. The Diesel-electric powertrain model presented in [11, 10] is a nonlinear mean value engine model (MVEM) containing four states and two control inputs. The problem solved here is a minimum fuel problem for a transient from idle to 170 kW, for an end time of 0.5 s. The control and state trajectories of the optimization results are shown in Figure 3 and Figure 4 respectively.

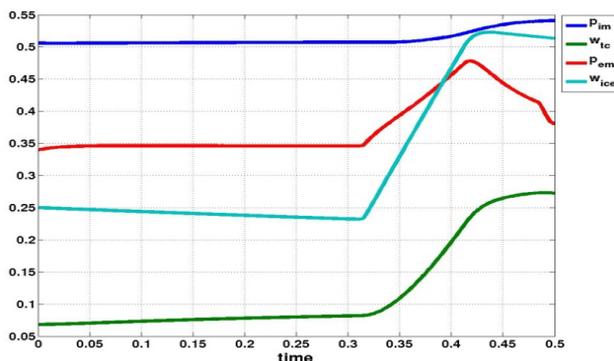


Figure 3: Optimization results of the Diesel-electric powertrain model—state variables.

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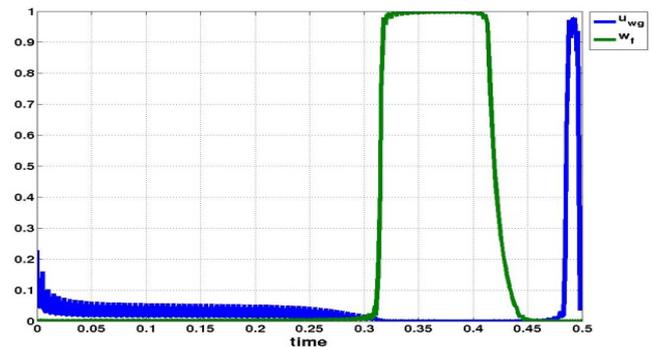


Figure 4: Optimization results the Diesel-electric powertrain model – control variables.

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