Master Theses in Development of Simulation, Optimization and Compiler Tools

Introduction

Simulation and optimization of dynamic systems is becoming a standard tool in several industrial branches. This trend is largely driven by the need to decrease product time-to-market. In order to increase productivity in the product design phase, model-based approaches are increasingly used. To meet the demand for model-based design methods and tools, domain specific languages have been developed. One such language is Modelica, which is a language targeted at modeling of complex heterogeneous physical systems. Modelica is currently used in a wide range of applications, including automotive systems, power plants, thermo-fluid systems, and robotics.

JModelica.org and OPTIMICA Compiler Toolkit

Most of the theses proposals in this document are related to JModelica.org (http://www.jmodelica.org), which is an open-source Modelica-based simulation and optimization environment, which also supports the Modelica language extension Optimica. A main part of the JModelica.org platform is the Modelica and Optimica compilers which are developed using the JastAdd framework. One product based on JModelica.org is OPTIMICA Compiler Toolkit (OCT). It is based on JModelica.org and extends it with several unique features. JModelica.org and OPTIMICA Compiler Toolkit is maintained and developed by Modelon AB (http://www.modelon.com).

Contact: Johan Åkesson, Modelon AB

Runtime instantiation in JModelica.org

Mostly, compilers perform runtime instantiation, allocating memory for instances during execution. In order to simplify the compilation process of Modelica the JModelica.org compiler performs instantiation during early compilation. We have identified a few cases where it can be beneficial to delay the instantiation until execution, or at least code generation, which would lead to reduced execution time and memory consumption for the compiler.

The aim of this thesis would be to implement the delayed instantiation for a few cases and give us an understanding of how it would work in more complex cases.

Student profile: Two skilled and motivated students, who has taken a course in compiler construction (preferably with good grades), and has interest in compiler development and Java programming.

Contact: Jonathan Kämpe, Modelon AB

Interactive HTML diagnostics in JModelica.org

Good compiler diagnostics is a powerful tool when debugging large models. JModelica.org currently have limited debugging diagnostics in the form of a few static HTML pages that are generated during compilation. The goal of the proposed master's thesis project is to further improve compiler diagnostics reports and utilize the powers of HTML, JavaScript and CSS to offer the user with a more interactive diagnostics tool. The different parts of the project are:

- Determining the requirements by surveying and interact with model developers and determine their workflow.
- Improve existing HTML diagnostics by incorporating CSS and JavaScript to visualize the relationship between equations, variables and their computation order.

Student profile: One skilled and motivated student with interest in compilers, Java, HTML, JavaScript and CSS development, who has taken a course in compiler construction.

Contact: Ola Wintzell, Modelon AB

High-performance storage of simulation data

Modern tools for simulation of large-scale dynamic systems are becoming a common technology in a wide range of industrial domains, including avionics, automotive, power plants, electronics and robotics. State of the art tools are capable of simulating models with more than 100.000 equations, which in turn generates large amounts of simulation data that needs to be stored in an efficient manner. To meet this need, a new data storage format is needed in JModelica.org. The task in this project is to investigate and evaluate existing storage format and, if relevant, propose a new format. The format is then to be implemented in the open source Modelica platform JModelica.org. The project includes several challenges, e.g., development of a user-friendly software design, learning industrial standards, and obtaining high performance. The implementation will be validated on industrial grade simulation models.

The project is done within the scope of the JModelica.org open source project.

Student profile: One skilled and motivated student with interest in numerical algorithms and programming. Prior knowledge of the C programming language, Modelica and XML is considered a merit, but is not mandatory.

Contact: Christian Winther, Modelon AB

Equation scaling in steady state solver

OPTIMICA Compiler Toolkit (OCT) contains non-linear equation solvers which are used for steady-state simulations and for solving the algebraic equations as a part of dynamics simulations. Scaling of the equations and iteration variables is utilized to compensate for ill-conditioned systems. Moreover, the solver takes into account the bounds on the iteration variables that indicate either model validity range or physically relevant regions.

In this project different scaling and re-scaling strategies are to be investigated. The scaling strategy should be implemented in a modular way and as an extension of the Kinsol and Minpack solver codes where additional debug logging will be inserted to facilitate the analysis. The project will include creating a collection of relevant test cases to be used as benchmarks.

The project will be run within the open-source JModelica.org platform at Modelon AB in Gothenburg.

Student profile: One (or two) skilled and highly motivated student(s) with interest in numerical algorithms and programming. Prior knowledge of C and MATLAB is considered a merit, but is not mandatory.

Contact: Iakov Nakhimovski & Agnes Ramle, Modelon AB

Development of strategies for model diagram layout

Component-based modeling of dynamic systems is becoming a standard technique in several industrial domains. The trend is largely due to the need to increase productivity in the product design phase. To meet the demand for component-based modeling, graphical modeling tools have been developed. An important factor in these tools is to enable an intuitive and user-friendly workflow for the modeler.

The aim of the thesis is to investigate different auto-layout algorithms and routing strategies for model diagrams regarding usability. The result is evaluated through user testing with simulation engineers.

Student profile: Two skilled and motivated students with interest in GUI development and programming. Prior knowledge of the Java programming language is considered a merit, but is not mandatory.

Contact: Victor Johnsson, Modelon AB

Dynamic support for mixing FMUs of different bitset

The Functional Mock-up Interface (FMI) is a standard designed to provide a unified model execution interface for dynamic system models between modelling and simulation tools. The standard has become highly successful with numerous tools, both commercial and open-source, supporting it. A foundation for many importing tools supporting the standard is the FMI Library, an open-source (C based) implementation that provides most of the low-level functionality necessary for working with models following the standard. The problem that many tools face is that the models are either 32bit or 64bit. This pose a problem when trying to integrate the models into a larger system model. This master thesis proposal aims at investigating and implement support in FMI Library to handle mixing of models with different bitset, potentially using a client/server setup.

Student profile: One (or two) skilled and highly motivated student(s) with interests in programming. Prior knowledge of C is mandatory.

Contact: Christian Winther, Modelon AB

Python model diagnostics package

Debugging models that are not initializing or simulating can take a lot of time and be very hard without useful debugging tools. The aim of this thesis is to create a Python package based on the output from the solvers in JModelica.org and diagnostics provided by the PyFMI package which gives the modeler clues about what can be changed in the model to reach convergence.

The challenge of the project is to find a bridge between the numerical issues in the different kinds of solvers that are part of JModelica.org FMUs and the original model. It requires deep understanding of the underlying solvers and what can cause problems. Creating smaller (problematic) example models on which the package is applied will be part of the project.

Student profile: One or two skilled and highly motivated student(s) with interest in numerical algorithms and programming. Prior knowledge of Python and C is considered a merit, but is not mandatory.

Contact: Agnes Ramle, Modelon AB

System modeling and simulation platform of the future

Modelon is building a system modeling and simulation platform of the future with the goal of creating a robust commercial platform available in the cloud. The solution needs highly interactive user interface for system modeling, massive parallelization of numerical simulations, post processing of large data sets and visualization in 2D and 3D. Collaborative system design preferred by modern engineers is a key capability of the platform, as well as high standards for IT security to keep sensitive customer product data safe.

As a master's thesis student, you will interact with experts within Modelon in a range of fields, including physical modeling, numerical algorithms, systems design and compiler technology, all disciplines needed to create a great system design platform. You will work closely with the development team and gain experiences with agile software development practices, including Scrum, code review and pair programming, all of which are key elements of Modelon's software development process.

We offer master's thesis projects in a **broad range of areas**, including:

- 3D visualization of system simulation, including vehicles
- 3D editing of system models
- Customized client web apps to support design workflows in model-based design
- Enhanced system modeling capabilities, e.g., icon editing and documentation generation, and composition of compiled models (FMUs)
- Advanced and configurable visualization of computational results (3D plots, scatter plots etc.)

Student profile: One or two skilled and highly motivated student(s) with interest in numerical algorithms and UI programming. Prior knowledge of Python, JavaScript and 3D applications is considered a merit.

Contact: Johan Åkesson, Modelon AB

United Technologies Corporation (Carrier) & Modelon Master's Thesis Project: Nonlinear Model Predictive Control Evaluation for HVAC Optimal Control

Summary

This Master Thesis topic is a collaboration between the Department of Automatic Control, Modelon and Carrier Corporation. The intent is to obtain problem formulations for the optimal control of HVAC equipment that captures operating constraints and performance targets and evaluates model characteristics, workflows and different tool environments.

Carrier Background and Importance of Control

UTC Commercial Businesses, comprised of OTIS and Climate Controls and Security, are the world's largest provider of building technologies. Its elevator, escalator, fire safety, security, building automation, heating, ventilation, air conditioning and refrigeration systems and services promote integrated, high performance buildings that are safer, smarter and sustainable. CCS and OTIS are units of United Technologies Corp., a leading provider to the aerospace and building systems industries worldwide.

Building systems, and HVAC systems in particular, are dynamic by nature. In addition, this type of equipment is subject to a number of hard constraints in operation due mainly to the protection of components including the compressor. This project will carry out trade studies to evaluate elements of a control design workflow that combines steady state information for set point determination and dynamic information for protection of the equipment and dynamic performance optimization.

The intent is to fully utilize Modelica models and to survey design methods and tools including but not limited to CasADi, Pyomo and OCT.

The objective of the project will be to create problem formulations for HVAC designs in collaboration with the industrial partner Carrier, to create workflows and to evaluate and implement nonlinear model predictive control (NMPC) to show the efficacy, advantages and trades for different problem formulations and models. In addition, model requirements (fidelity, characteristics as smoothness) will be included in the trade study.

Student profile

One or two skilled and highly motivated student(s) with interest in numerical algorithms, automatic control and programming. Prior knowledge in automatic control and optimal control is a requirement. Python programming is a merit but not mandatory.

Supervisors:

- Department of Automatic Control, Lund University. Pontus Giselsson.
- Modelon. Johan Åkesson, Magdalena Axelsson.
- Carrier. Kristian Tuszynski, Clas Jacobson.

Contact: Magdalena Axelsson, Modelon AB