Detailed Course Plan, 2020

Model-Based Systems Engineering

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Introduction

This is an introductory course in systems engineering with emphasis on model-based systems development, design, and analysis using tools. The course include general methods which are useful within a range of system engineering domains, e.g., computer science, software engineering, machine design, electrical engineering, vehicular systems, aerospace applications, transport systems, project management, sustainability life cycle design and analysis, maintenance.

After the course, students should be able to:

- Describe how products and services from different technical areas can be integrated into a system.
- Describe basic concepts in Systems Engineering.
- Specify and analyze system requirements.
- Design and model a system architecture.
- Use modeling languages such as Modelica and UML to describe a small system.
- Model, analyze, simulate, and optimize a system.
- Plan implementation of a system.
- Validate a system.
- Perform environmental and lifecycle analysis of a system.

There is also an optional INCOSE provided course part mainly on management and organizational aspects of industrial systems engineering, giving INCOSE CSEP/ASEP certification. This course part is also given as an internal course at Saab and recommended for managers. It also demonstrates systems engineering at SAAB Aeronautics VLS.

Course Credits

6 HEC

It is possible to get 1-3 extra credits for a small project of your own choice, or an extended version of an electrical vehicle modeling project or long-range electrical aircraft project.

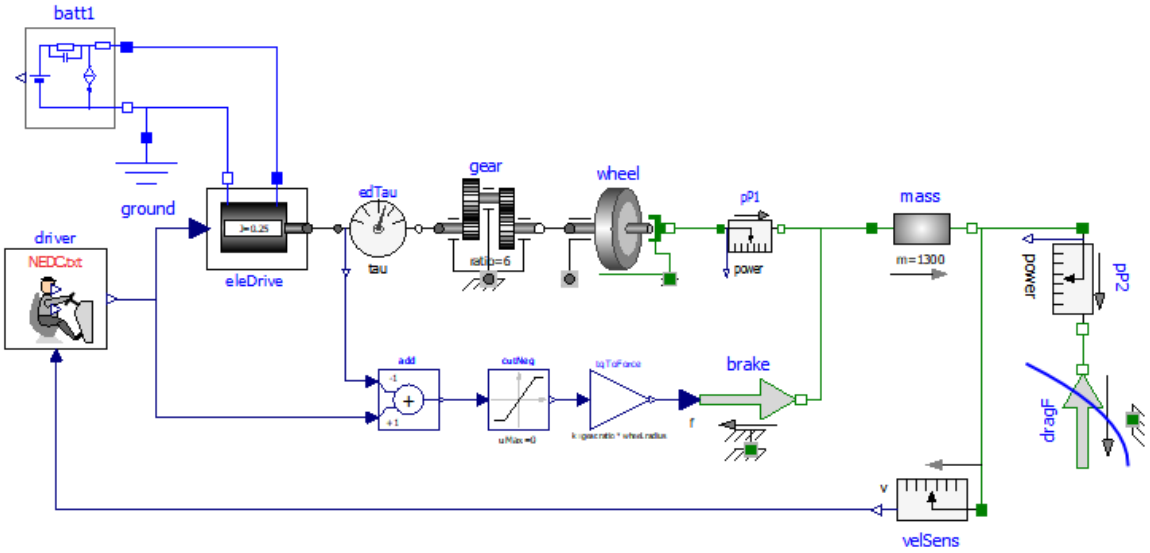
People who already know Modelica can/should skip the two Modelica course days and the associated theoretical matter. However, to compensate, they should suggest a small project or related theoretical matter of their own choice, to be approved by the course leader.

On top of this, is also possible to get an additional 4 credits for an extra add-on INCOSE provided course part mainly on management and organizational aspects of systems engineering, giving INCOSE certification. This will be given as 8-9 extra 2h lectures with associated presentations and final written exam. Lecturer: Erik Herzog. If you are interested, contact Erik.Herzog@saabgroup.com.

Case Study with an Electric Vehicle (or Electric Aircraft)

The course contains a case study with the design of a plug-in charging electric vehicle. This includes system analysis, design, modeling and simulation, requirement formalization and verification, choice of components, optimization goal, etc.

The plug-in electric vehicle model has the following very simplified schematic connection diagram:



A model library in Modelica with model components relevant for electric cars will be made available. Tool support for modeling, simulation, requirement formalization, requirement verification, optimization, etc. will be available using OpenModelica.

Optionally, you may instead choose to do the modeling project on modeling and optimizing an electric aircraft for long distance flights (supervision by Ingo Staack and Robert Braun), or another project of the same complexity after approval by the course leader.

Course Literature

- Peter Fritzson. Principles of Object-Oriented Modeling and Simulation with Modelica 3.3. Wiley-IEEE Press, 2015. Selected parts
- Donella Meadows. Thinking in Systems. Chelsea Green Publishing, 2008 and 2018.
- Peter Fritzson. The DrModelica Interactive Electronic Notebook. Available in OMNotebook in the OpenModelica installer and on the web: http://omwebbook.openmodelica.org/DrModelica
- Functional Mockup Interface (FMI) Overview. Slide presentation.
- Slide presentation and papers on optimization

- Slide presentation and papers on systems engineering
- Optional part: INCOSE systems engineering certification; slides

Detailed Overview of Lectures and Schedule

Organizational Aspects

Lecture Rooms

Main lecture room John von Neumann, Dept. Computer and information Science, House B, Campus Valla, Linköping University.
https://www.ida.liu.se/department/location/search.en.shtml?keyword=John+von+Neumann

Some lectures in: room Donald Knuth,
https://www.ida.liu.se/department/location/search.en.shtml?keyword=Donald+Knuth

Detailed schedule to be provided at first lecture.

Main Course starts in Donald Knuth Feb 10 at 09.00.
Intro Lecture Feb 7 at 15.15 in room John von Neumann

All lectures in John von Neumann, except
Monday Feb 10, 9-10 in Donald Knuth, and Monday March 2 , 8.15-10, in Donald Knuth

To participate

If you are from the IDA department at LIU, use the usual PhD course application mechanism.

If you are from another department at LIU or from an organization external to LIU, send a course application email to anne.moe@liu.se specifying your name, study background, motivation for taking the course, affiliation, group, address, email address, mobile phone number.

Day 0, February 7 15.15-16.30 General Introductory Lecture

Lecturers: Johanna Axehill Wallén
"Why is it difficult to develop cyber-physical systems"

Day 1, February 10 9.00-17.00 Modelica Introduction part 1

Lecturers: Peter Fritzson

Lecture Introduction to Modeling and Simulation with Modelica and OpenModelica

Short **presentations by participants** about their interests, 3 min each. Email 1 slide each beforehand.

Introduction to Modelica and OpenModelica

Demo+short exercise: Graphic modeling with OMEdit

OpenModelica OMNotebook usage

Introduction to textual modeling

Demo+Exercise: OMNotebook and DrModelica

Lecture Modelica Classes, Inheritance and Equations

Lecture+Exercises: classes and inheritance

Exercise01-classes-simple-textual.onb

Lecturing on Modelica equations.

Exercise03-classes-textual-circuit.onb

Lecture – Modelica Connectors, Packages and Libraries

Lecturing+Exercises: Component connectors and connections, graphical modeling

Exercise02-graphical-modeling.onb

Lecturing on Modelica packages and libraries

Lecture – 3D Graphics with 3D animation

Lecture and exercise on 3D graphics

Lecture – Model Debugging

Lecture and exercise on model debugging.

Day 2, February 11, 08.15-16.30 Modelica Introduction part 2 Functions Hybrid

Lecturers: Lena Buffoni

Lecture – Modeling Approaches

Lecturing on state-space, block diagram, component approaches. Also Flat tank with controller.

Lecture – Graphical Modeling with Control Feedback

Lecturing and exercise on adding a feedback loop with controller to the DCMotor.

Lecture – Modelica Hybrid Systems Including Clocked and State Machines

Lecturing and Exercise05-hybrid-discreteevent.onb

Small exercise on clocked synchronous and/or state machine constructs.

Lecture – Modelica Algorithms and functions

Lecturing and Exercise04-equations-algorithms-functions.onb

Lecture – Modelica External Function Interface

Lecturing and Exercise on using Modelica's external function interface

Day 3, February 12 , 08.15-17.00 Modelica intro cont Requirements Verification

Lecturers: Lena Buffoni,

Half day, Modelica introduction, Own study, continued exercises; Lena Buffoni

Half day, 13.15-17.00, afternoon

Lecture – Formalization of Requirements and Dynamic Model-Based Verification

Lecture and hands-on exercise using OpenModelica on requirement modeling and dynamic verification.

Day 4, February 13 , 08.15-16.00 Systems Engineering Basic Concepts

Lecturers: Erik Herzog

Lecture – Systems Engineering, Basic Concepts I

Basic concepts. Industry perspective.

Lecture – Systems Engineering, Basic Concepts II

Continued. Basic concepts.

Day 5, February 14 , 08.15-16.00 Electric Vehicle Modeling

Lecturers: Lars Eriksson

Lectures – Electric Vehicle Modeling

Introduction to electric vehicles and their modeling and simulation. Introduction to the electric vehicle case study.

Exercises on the electric vehicle model

Very short introduction to the model-based optimization case for this application and the OpenModelica optimization tool facilities.

Extra Day, February 25, 10.15-15.00 Electric Vehicle Modeling Exercise Support

Lecturers: Lars Eriksson
Here you will get more help with the electric vehicle modeling project.

Day 6, March 2 08.15-17.00 Lectures – Thinking in Systems and Sustainability

Lecturers: Ola Leifler, Peter Fritzson

Lecturing on systems thinking, complexity, life cycle

Exercises on modeling such aspects of a system

Day 7, March 3 8.15-17.00 Model-based System Optimization

Lecturers: Robert Braun

Lecture – Model-Based System Optimization, Part I

Introduction to methods and tools to optimize a system based on a model, and design exploration.
Exercises

Lecture – Model-Based System Optimization, Part II

Part II of methods and tools to optimize a system based on a model, and design exploration.
Exercises

Day 8, March 4 Functional Mockup Interface, 08.15-17.00

Lecturers: Lennart Ochel
½ day, Functional Mockup Interface (FMI), Lecture and exercises 8.15-12.00
1/2 day, Own study, 2h exercise support (Lennart Ochel)

Day 9, March 5, Own Study Day and Vehicle case study cont, 08.15-17.00

Lecturers: Lars Eriksson

Lars is available part of the day to answer questions and give advice on the electrical vehicle application case study modeling. The lecture room is reserved for own and group work 8.15-17.00.

Day 10, March 6, 08.15-15.00

Lecturer: Kristian Sandahl

Lecture – UML

Catch-up lecture for those that are unfamiliar with UML

Use-cases, classes, sequence diagrams, and state charts. Standard UML
Exercises with Papyrus UML Tool

Lecture – System Anatomy

Introduction and practical exercise in creating a system anatomy as a way to create a common internal view of a system.

Examination day: To be decided. April 2020. (if this does not work for you, contact the course leaders)