Detailed Course Plan

Model-Based Systems Engineering

Peter Fritzson, Kristian Sandahl, Ola Leifler, Lars Eriksson, Lena Buffoni, Tomohiko Sakao, Petter Krus, Bernhard Thiele, Erik Herzog

Introduction

This is an introductory course in systems engineering with emphasis on model-based systems development, design, and analysis using tools. The course includes 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 SysML to describe a small system.
- Model, analyze, simulate, and optimize a system.
- Plan implementation of a system.
- Validate a system.
- Perform environmental and lifecycle design and management of a system.

Case Study with a Hybrid Electric Vehicle

The course contains a case study with the design of a plug-in charging hybrid electric vehicle. This includes system analysis, design, modeling and simulation, requirement formalization and verification, choice of components, optimization to minimize CO2 emissions, life-cycle analysis, etc.

The plug-in hybrid electric vehicle model has the following schematic connection diagram:
A model library in Modelica with model components relevant for hybrid electric cars will be made available. Tool support for modeling, simulation, requirement formalization, requirement verification, optimization, etc. will be available using OpenModelica.

**Overview of Lectures and Schedule**

**Day 1, Oct 19 10.15-17.00**

Lecturers: Lena Buffoni, Bernhard Thiele, Peter Fritzson

**Lecture Introduction to Modeling and Simulation with Modelica and OpenModelica**

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 (Lena)
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 (Lena)
Exercise02-graphical-modeling.onb
Lecturing on Modelica packages and libraries
Day 2, Oct 20, 08.15-16.00
Lecturers: Bernhard Thiele, Lena Buffoni

**Lecture – Graphical Modeling with Control Feedback**
Lecturing and exercise on adding a feedback loop with controller to the DCMotor.

**Lecture – Modelica Algorithms and functions**
Lecturing and Exercise04-equations-algorithms-functions.onb

**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.

Day 3, Oct 21 08.15-16.00
Lecturers: Lars Eriksson, Bernhard Thiele

**Lecture – Hybrid Electric Vehicle Modeling and Optimization**
Introduction to hybrid electric vehicles and their modeling and simulation. Introduction to the hybrid electric vehicle case study.
Very short introduction to the model-based optimization case for this application and the OpenModelica optimization tool facilities.

Day 4, Oct 22, 08.15-16.00
Lecturers: Ola Leifler, Erik Herzog

**Lecture – Systems Engineering, Basic Concepts I**
Basic concepts according to the course book. Industry perspective.

**Lecture – Personal Presentations, 5-7 min per Course Participant**
Each course participant makes a short 5-7 min slide presentation about their own background and research and/or application interests in this topic.

**Lecture – Systems Engineering, Basic Concepts II**
Continued. Basic concepts according to the course book.

**Lecture – Personal Presentations, 5-7 min per course participant**
Continued personal presentations.

Day 5, Oct 23, 08.15-15.00
Lecturers: Tomohiko Sakao, Lena Buffoni

**Lecture – Lifecycle Design and Product/Service Systems**
Lecturing on lifecycle design and Product/Service Systems
Exercise on modeling environmental and economic aspects of a system

**Lecture – Formalization of Requirements and Dynamic Model-Based Verification**
Lecture and hands-on exercise using OpenModelica on requirement modeling and dynamic verification. Lecturers: Bernhard Thiele, Lena Buffoni
Own Study Day,  Oct 26, 08.15-12.00
Lecturers: Lars Eriksson, Bernhard Thiele
Lars and/or Bernhard are available 8.15-10.00 to answer questions and give advice on the application case study. The lecture room is reserved for own and group work 8.15-12.00.

Own Study Day,  Oct 27, 08.15-12.00
Lecturers: Lars Eriksson, Bernhard Thiele
Lars and/or Bernhard are available 8.15-10.00 to answer questions and give advice on the application case study. The lecture room is reserved for own and group work 8.15-12.00.

Own Study Day,  Oct 28, 08.15-12.00
Lecturers: Lars Eriksson, Bernhard Thiele
Lars and/or Bernhard are available 8.15-10.00 to answer questions and give advice on the application case study. The lecture room is reserved for own and group work 8.15-12.00.

Day 6,  Oct 29, 10.15-17.00
Lecturers: Petter Krus

Lecture – Model-Based System Optimization, Part I
Introduction to methods and tools to optimize a system based on a model, and design exploration.

Lecture – Model-Based System Optimization, Part II
Part II of methods and tools to optimize a system based on a model, and design exploration.

Own Study – Application Case Study
Later in the afternoon, 15.15-17.00, own work on the application case study. Lars and/or Bernhard available to give advice.

Day 7,  Oct 30, 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

Lecture – Life cycle management

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: Nov 24. (if this does not work for you, contact the course leaders)