

Distance teaching of continuous-time modeling and simulation using Modelica

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Outline

1. What is Modelica?
2. Why do I use Modelica for teaching?
3. An example of using Modelica in teaching M&S



Master's Degree (at distance)
in System and Control Engineering

4. InMotion books and MOOC by the UNED group

What is Modelica? (1/2)

Modelica is a non-proprietary modeling language

The first version of Modelica was released in 1997

Actual version: Modelica 3.5

Modelica is intended to:

- Serve as standard language for exchange of models
- Facilitate object-oriented, equation-based modeling
 - Modelica simulation environments automatically manipulate symbolically the model to generate the simulation code
- Promote model reuse, facilitating development of model libraries

What is Modelica? (2/2)

General-purpose language, not tied to a particular physical domain

Models are described in Modelica as a combination of:

- Differential equations with derivative with respect to time
- Algebraic equations
- Discrete-time equations, and events
- Algorithms and functions

There exist mature Modelica tools

- Dymola
- OpenModelica
- Wolfram SystemModeler
- etc.

and many model libraries written in Modelica

Modelica Association - non-profit organization
coordinates development of Modelica

<https://modelica.org/modelicalanguage.html>

Why do I use Modelica for teaching M&S?

- Well suited for describing the type of models most commonly used in Control Engineering
 - models of multi-domain cyber-physical systems,
 - described as differential-algebraic equations (DAE), and events
- Well suited for explaining to students concepts on
 - Modeling of mixed-domain physical systems
 - Object-oriented modeling methodology
 - Algorithms for DAE analysis (partition, DAE index reduction)
 - Numerical methods for continuous-time models with events
- Practical interest: Modelica is used in academia and industry
- It is also a choice based on my personal preference

An example:

Distance teaching of continuous-time
modeling and simulation in the
Master's Degree in
System and Control Engineering

Master's Degree in System and Control Engineering

2 universities: UNED, and Complutense University of Madrid

Distance learning

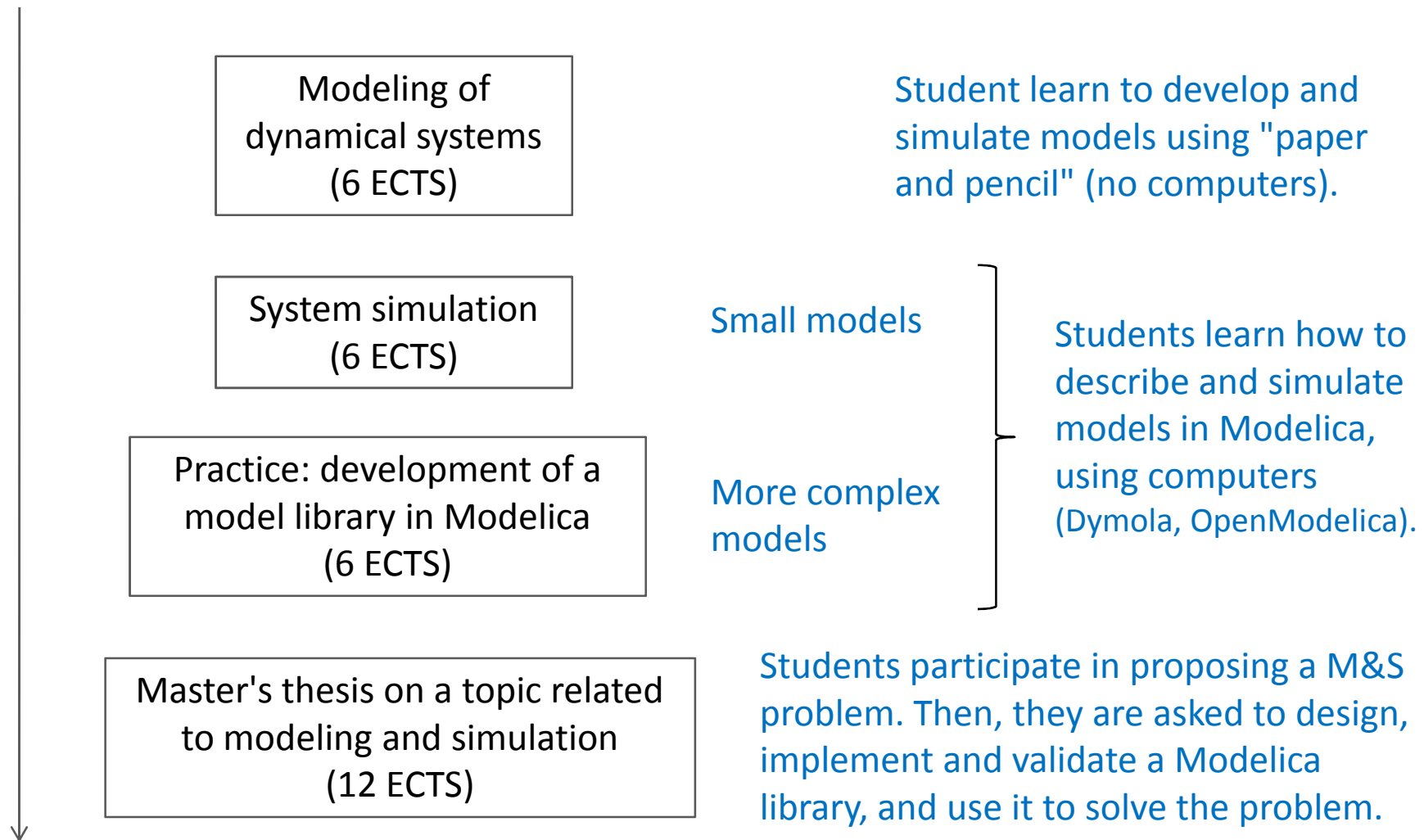
60 ECTS = 8 elective subjects (6 ECTS per subject) + Master's thesis (12 ECTS)

Groups of subjects

1. Mathematics and computation
2. Computers and communications
3. Sensors and signal processing
4. Robotics and industrial automation
5. Modeling and simulation ← 2 subjects:
 - Modeling of dynamical systems (6 ECTS)
 - System simulation (6 ECTS)
6. Control
7. Bio-inspired technology
8. Practice ← Development of a model library in Modelica (6 ECTS)
9. Master's thesis ← Modeling and simulation projects (12 ECTS)

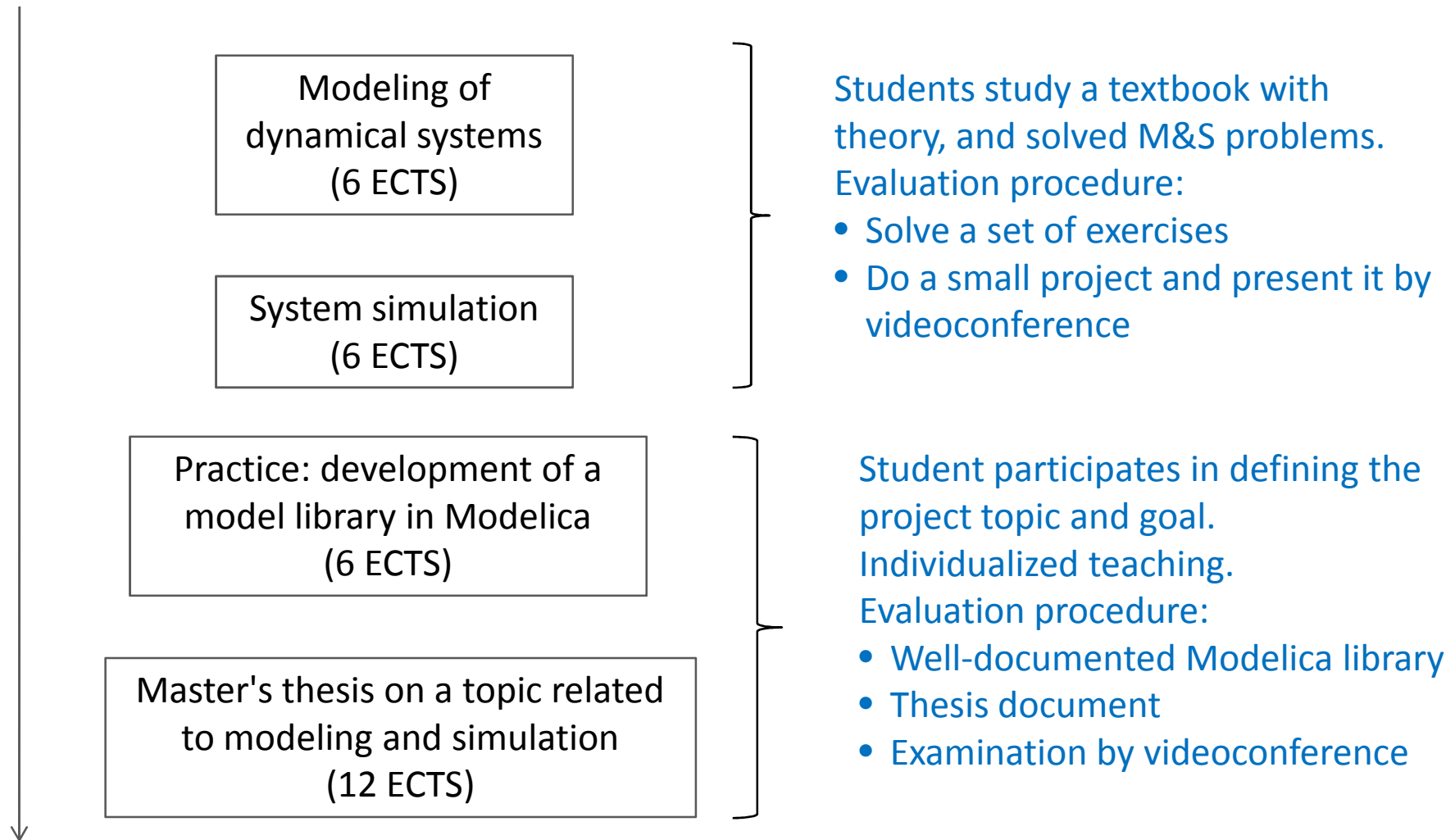
Pedagogical approach

Students' itinerary through M&S subjects



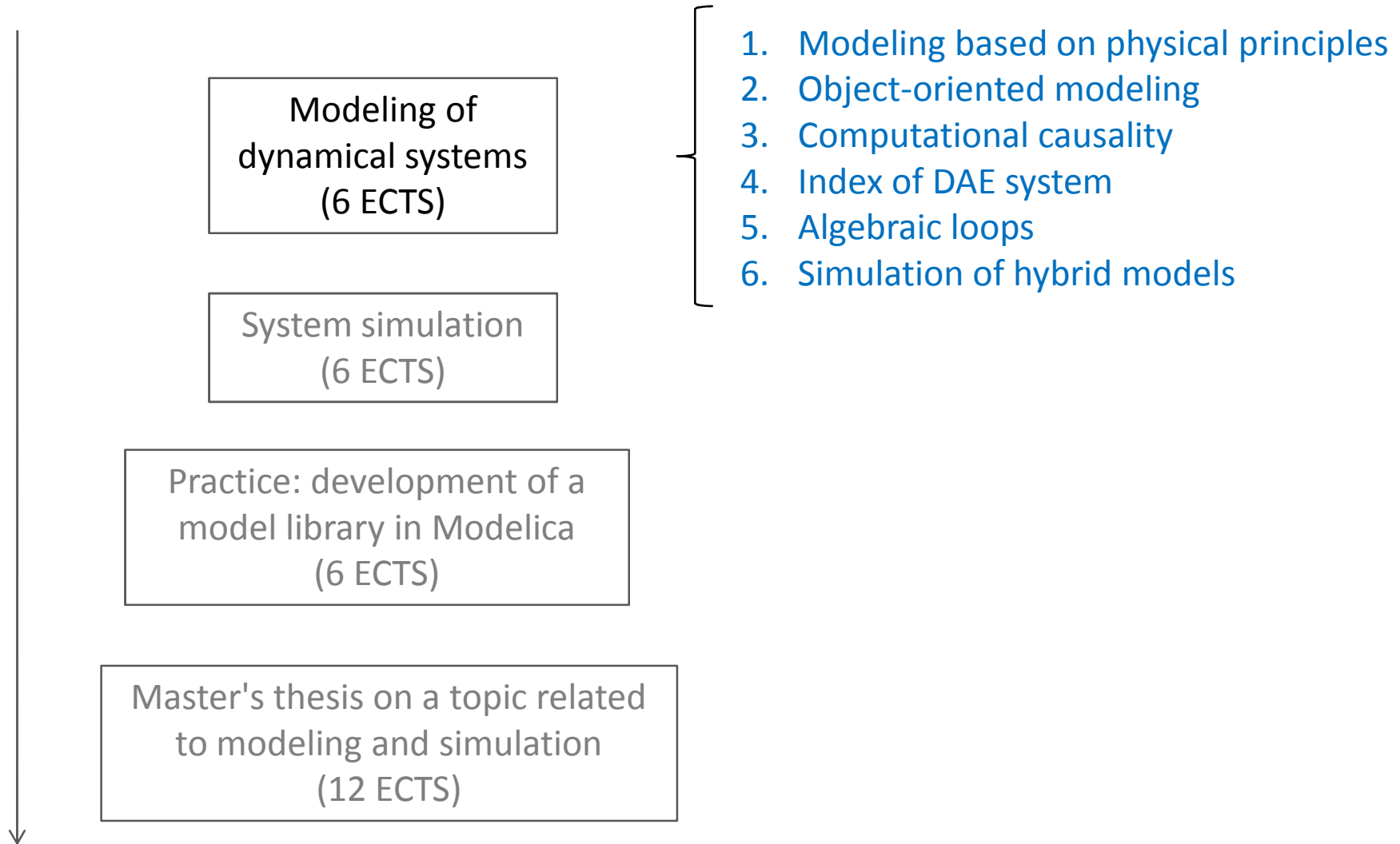
Teaching methodology

Students' itinerary through M&S subjects



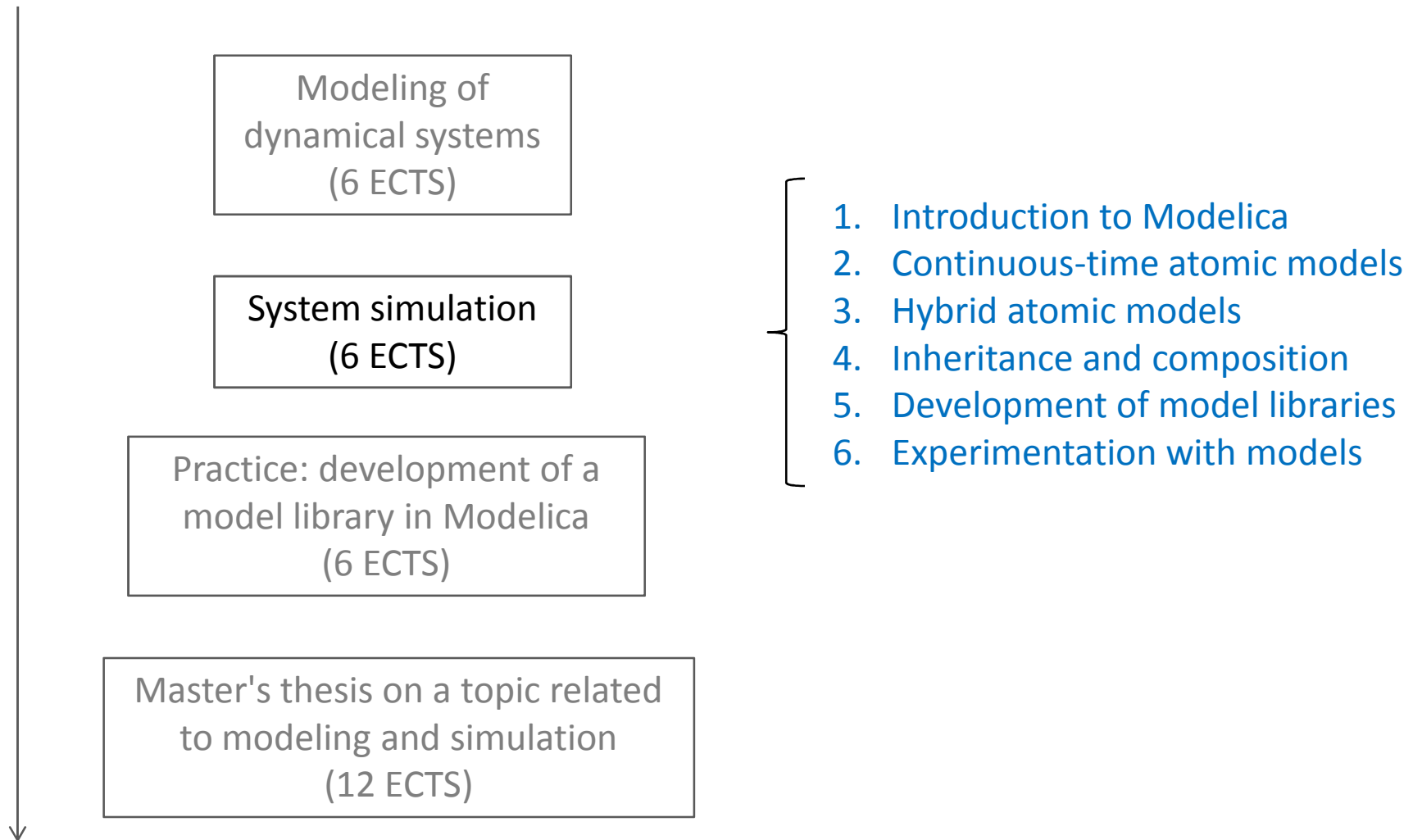
Contents (1/2)

Students' itinerary through M&S subjects



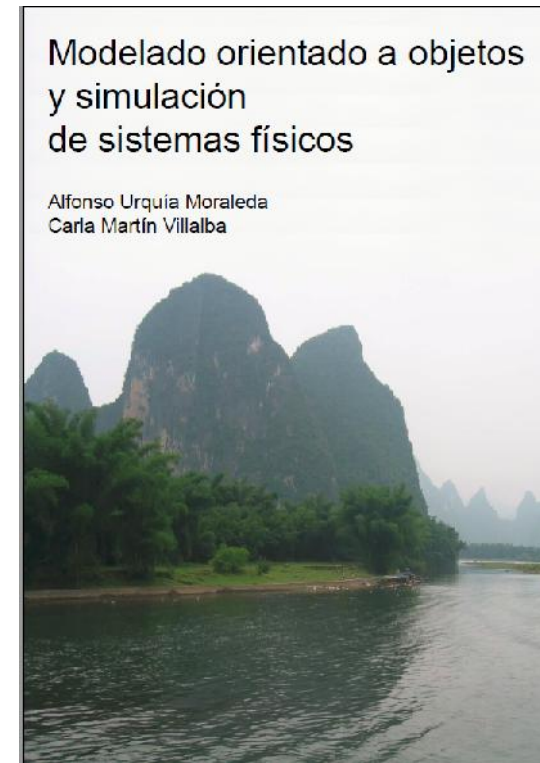
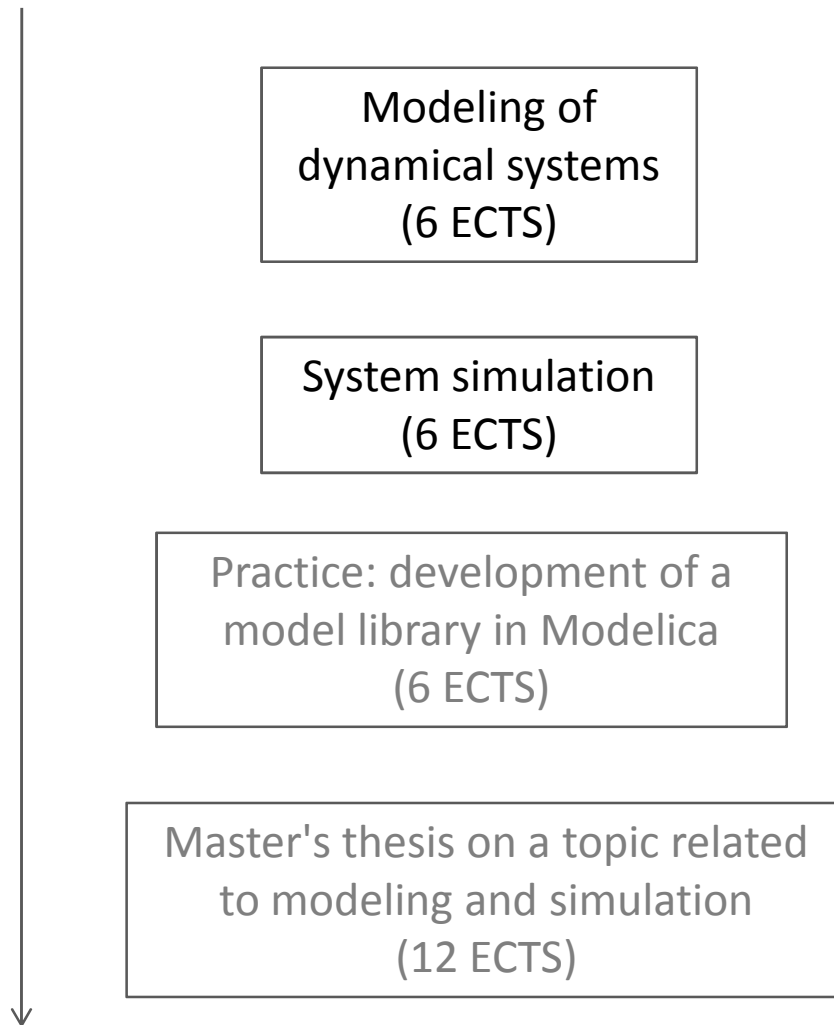
Contents (2/2)

Students' itinerary through M&S subjects



Teaching material (1/4)

Students' itinerary through M&S subjects



+

Cellier, F.E.; Kofman, E.: "*Continuous System Simulation*". Springer, 2006.

+

A selection of papers

Teaching material (2/4)

Compulsory readings

- Broenink, J.F.: Introduction to Physical Systems Modelling with Bond Graphs.
- Åström, K.J.; Elmqvist, H.; Mattsson, S.E.: Evolution of continuous-time modeling and simulation.
- Elmqvist, H.; Mattsson, S.E.; Otter, M.: Modelica - An international effort to design an object-oriented modeling language.
- Cellier, F.E.; Kofman, E.: Continuous System Simulation. Springer. Chapters 7 and 9.
- Elmqvist H.; Otter M.; Cellier F.E.: Inline integration: a new mixed symbolic/numeric approach for solving differential algebraic equation systems.
- Elmqvist H.; Mattsson S.E., Olsson H.: New methods for hardware-in-the-loop simulation of stiff models.
- Schiela A.; Olsson H.: Mixed-mode integration for real-time simulation.
- Elmqvist, H.; Cellier, F.E.; Otter M.: Object-oriented modeling of hybrid systems.
- Johansson, K.H.: The quadruple-tank process: a multivariable laboratory process with an adjustable zero.

Teaching material (3/4)

Complementary readings

- H. Olsson; M. Otter; S.E. Mattsson; H. Elmqvist (2008). Balanced models in Modelica 3.0 for increased model quality.
- R. Franke et al. (2009). Stream Connectors - An extension of Modelica for device-oriented modeling of convective transport phenomena.
- M. Otter; F. Casella (2009). Overview and rationale for Modelica stream connectors.
- M. Otter et al. (2009). A new formalism for modeling of reactive and hybrid systems.
- H. Elmqvist et al. (2012). State machines in Modelica.
- M. Otter; B. Thiele; H. Elmqvist (2012). A library for synchronous control systems in Modelica.
- H. Elmqvist; M. Otter; S.E. Mattsson (2012). Fundamentals of synchronous control in Modelica.
- F. Casella; M. Sielemanny; L. Savoldelli (2011). Steady-state initialization of object-oriented thermo-fluid models by homotopy methods.
- Modelica Association (2000). Tutorial of Modelica 1.4.

Teaching material (4/4)

Some more complementary readings

- P. Fritzson (2003). Introduction to modeling and simulation of technical and physical systems.
- H. Elmqvist; S.E. Mattsson; M. Otter (2000). Object-oriented and hybrid modeling in Modelica.
- S.E. Mattsson; H. Olsson; H. Elmqvist (2000). Dynamic selection of states in Dymola.
- M. Otter; H. Olsson (2001). New features in Modelica 2.0.
- S.E. Mattsson; H. Elmqvist; M. Otter; H. Olsson (2002). Initialization of hybrid differential-algebraic equations in Modelica 2.0.
- H. Elmqvist; M. Otter (1994). Methods for tearing systems of equations in object-oriented modeling.
- C.C. Pantelides (1988). The consistent initialization of differential-algebraic systems.
- P. Bunus; P. Fritzson (2002). Methods for structural analysis and debugging of Modelica models.
- P. Fritzson et al. (2002). The open source Modelica project.

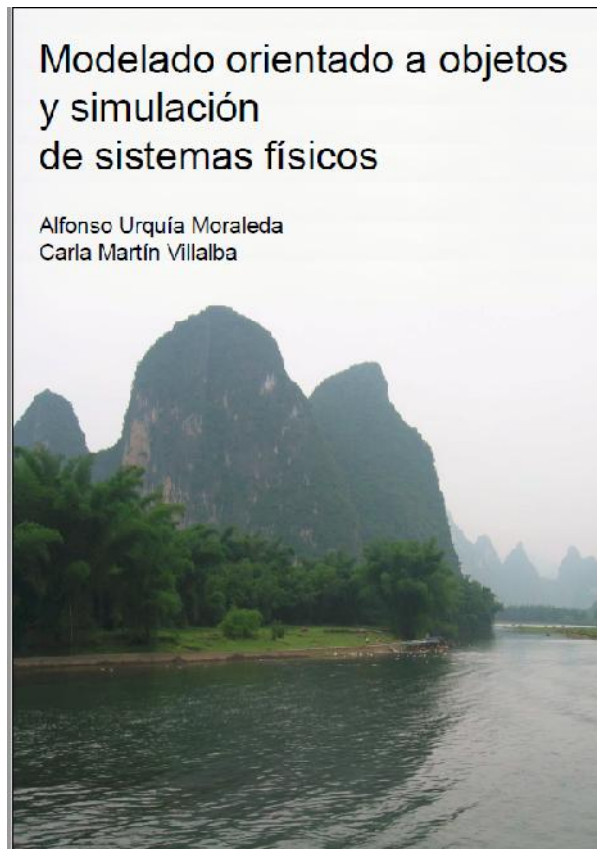
Books and MOOC developed by the UNED group within the InMotion project



ERASMUS+ project
<http://www.inmotion-project.net>



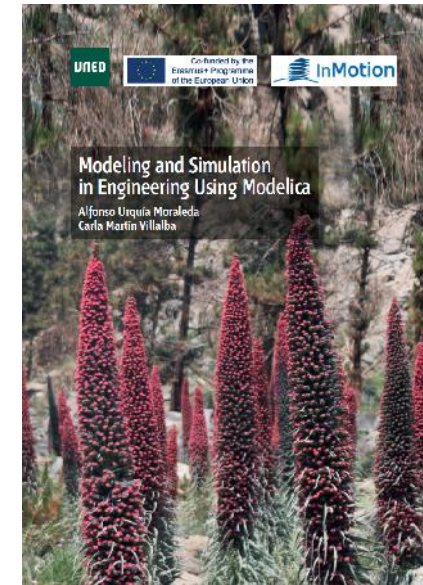
InMotion books by the UNED group



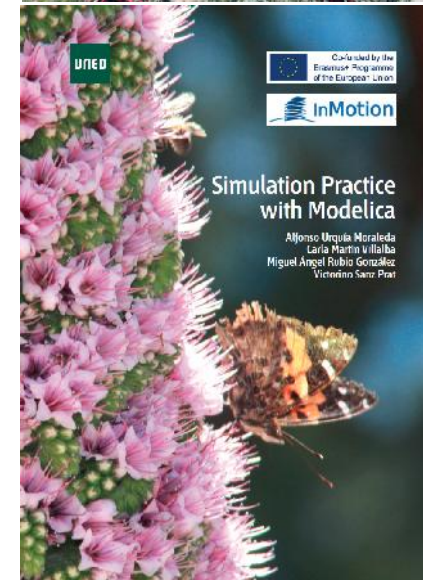
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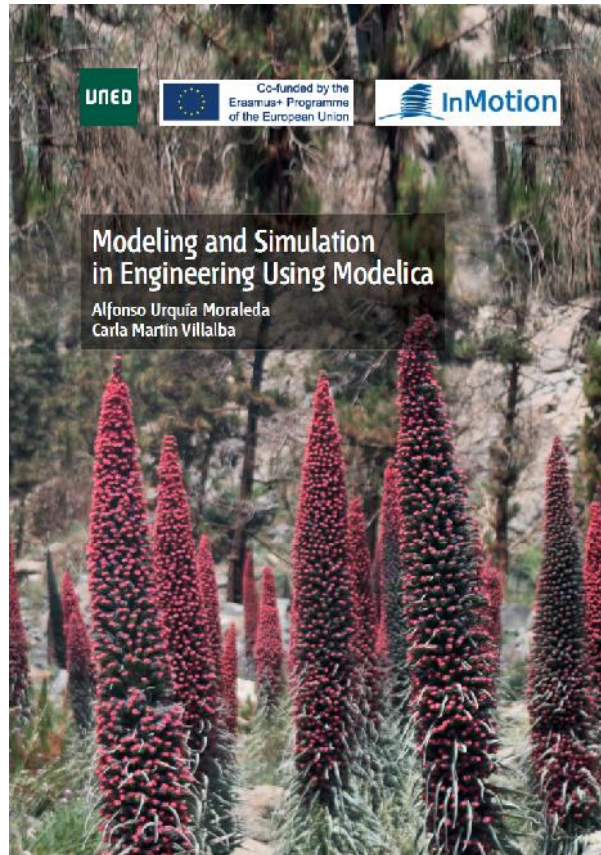
Theory



Assignments



Theory book (1/2)



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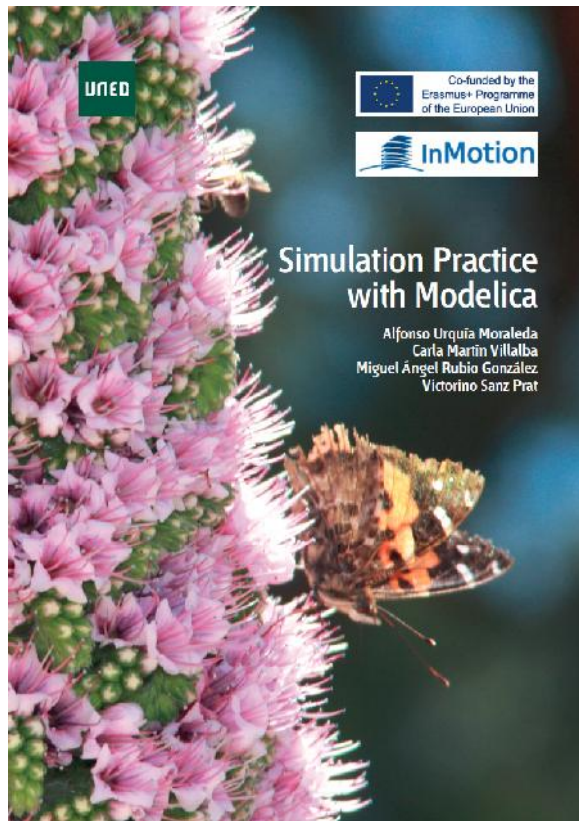
<http://www.librosuned.com/compras/detalle.aspx?isbn=9788436273090>

Theory book (2/2)

Contents

Modelica code	11	Lesson 5 Index and initialization of DAE systems	137
Preface	13	5.1 Introduction	138
I Continuous-time modeling		5.2 Structurally singular DAE systems	138
Lesson 1 Modeling methodology and tools	19	5.3 Index of DAE systems	146
1.1 Introduction	20	5.4 Initialization of DAE systems	157
1.2 Physical modeling paradigm	20	5.5 Selection of the state variables	167
1.3 Object-oriented modeling	23	5.6 Further reading	179
1.4 Modeling environments	26	Lesson 6 Numerical methods	181
1.5 Getting started with Modelica	29	6.1 Introduction	182
1.6 Further reading	42	6.2 Systems of simultaneous equations	182
Lesson 2 Continuous-time atomic models	45	6.3 Numerical solution of ODE	187
2.1 Introduction	46	6.4 Numerical solution of DAE	192
2.2 Rectifier circuit	46	6.5 Further reading	194
2.3 Translation in one dimension	56	III Hybrid system modeling and simulation	
2.4 Translation in two dimensions	61	Lesson 7 Hybrid system specification	197
2.5 Radial heat transfer in a pipe	69	7.1 Introduction	198
2.6 Further reading	75	7.2 The OHM formalism	198
Lesson 3 Model libraries	77	7.3 Model specification and simulation algorithm	200
3.1 Introduction	78	7.4 Model specification and Modelica description	202
3.2 Electrical library	78	7.5 Models with a variable structure	213
3.3 Longitudinal vibrations of a bar	92	7.6 Model initialization	223
3.4 Longitudinal heat conduction in a bar	96	7.7 Further reading	234
3.5 Control of level and temperature in a tank	101	Lesson 8 Event detection and handling	235
3.6 Dissipation of heat generated in a circuit	114	8.1 Introduction	236
3.7 Further reading	117	8.2 Simultaneous events	236
II Simulation of continuous-time models		8.3 Crossing function	242
Lesson 4 Computational causality	121	8.4 Determination of the event instant	248
4.1 Introduction	122	8.5 Chattering	250
4.2 Classification of the model variables	122	8.6 Further reading	254
4.3 Structural singularity	125	Lesson 9 Hybrid modeling practice	255
4.4 Partition algorithm	126	9.1 Introduction	255
4.5 Overdetermined and underdetermined systems	128	9.2 Ideal electric switch	263
4.6 Example: simulation of an electrical circuit	130	9.3 Ideal diode	265
4.7 Further reading	136	9.4 Two-tank and valve system	269
		9.5 Bouncing ball	272
		9.6 Dry friction	274
		9.7 Heat conduction in a wall	282
		9.8 Further reading	290
		Subject Index	291
		References	295

Assignment book (1/2)



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Assignment book (2/2)

Contents

- Assignment 1 Springs, damper and lever
- Assignment 2 Springs, pulley and load
- Assignment 3 Bond graph library
- Assignment 4 Source of liquid
- Assignment 5 Ideal gas in a heated container
- Assignment 6 Hysteresis controller
- Assignment 7 Draining of a benzene storage tank
- Assignment 8 Heating a liquid mixture
- Assignment 9 Double-pipe heat exchanger
- Assignment 10 Cellular Automata – The Game of Life
- Assignment 11 Air pollution
- Assignment 12 Simplified Tennessee Eastman model
- Assignment 13 PEM fuel cell

InMotion MOOC by the UNED group

https://iedra.uned.es/courses/course-v1:UNED+Modelsimul_004+2022/about

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English

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Modeling and simulation in Engineering using Modelica (4^aed. 2022)

- > PREFACE
- > LESSON 1 - MODELING METHODOLOGY AND TOOLS
- > LESSON 2 - CONTINUOUS-TIME ATOMIC MODELS
- > LESSON 3 - MODEL LIBRARIES
- > LESSON 4 - HYBRID MODELING
- > Course assessment survey



Classes Start

15 February 2022



Classes End

30 April 2022



Estimated Effort

25 horas

Thanks for your attention!!