جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Course Syllabus: Contemporary Topics in Systems - EE 394J

Division	Computer, Electrical and Mathematical Sciences & Engineering
Course Number	EE 394J
Course Title	Contemporary Topics in Systems
Academic Semester	Summer
Academic Year	2018/2019
Semester Start Date	06/16/2019
Semester End Date	08/08/2019
Class Schedule (Days & Time)	01:00 PM - 04:00 PM | Wed Thu

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Luigi Vanfretti	LUIGI.VANFRETTI@KAUST.EDU.SA			Wed Thu 4:00 - 5:00 PM or by appointment. Office 0237, Building 5.

Teaching Assistant(s)

Name	Email
Guang Ooi	guang.ooi@kaust.edu.sa

Course Information

Comprehensive Course Description	This course develops a solid basis for students to model and simulate cyber-physical systems using computer-based object-oriented equation-based modeling languages and tools with the goal of building models with high reusability. The course covers both theoretical and practical issues related to numerical simulation methods for CPS, including continuous time, discontinuous/discrete and timed clocked systems. Aspects of code-generation and real-time simulation for embedded systems are introduced. These foundations allow for the modeling and simulation of embedded systems which will be carried out “virtually” (by simulation) and physically using the Arduino.
Course Description from Program Guide	

Goals and Objectives

Course goals/objectives

Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the seamless integration of computation and physical components. Advances in CPS will enable capability, adaptability, scalability, resiliency, safety, security, and usability that will expand the horizons of these critical systems. CPS technologies are transforming the way people interact with engineered systems, just as the Internet has transformed the way people interact with information. New, smart CPS drive innovation and competition in a range of application domains including aeronautics, building design, energy, electrical power grids, healthcare, manufacturing, and transportation, to name a few.

In this course students will develop and master a tool set of theory, methods, computer languages and software tools for modeling and simulating cyber-physical systems. Utilizing these skills, the students will be able to architect, model, design, simulate and analyze dynamic characteristics of cyber-physical systems that are critical for society and have the possibility to transform the way humans interact with engineered systems.

Student Learning Outcomes

1. ***Comprehend*** the fundamental principles of modeling and simulation of continuous, discrete, hybrid and timed-clocked systems that lead to the formulation of cyber-physical system models.
2. ***Comprehend*** and ***apply*** computer-and-equation based object-oriented languages for modeling of cyber-physical systems using the Modelica language.
3. ***Comprehend*** and ***explain*** *the methods* used for symbolic transformation of computer models, efficiency issues in numerical solutions and effect of nonlinearities, higher-and-varying index problems, initialization methods, event handling, and other numerical issues related to mathematical solvers used for simulation and co-simulation.
4. ***Construct*** simulation models for cyber-physical systems using the Modelica language in Modelica Environments such as Dymola and OpenModelica.
5. ***Comprehend*** and ***explain*** the concept of real-time simulation, and hardware-in-the-loop simulation.
6. ***Comprehend*** concepts of embedded systems and ***apply*** solutions for real-time simulation.

Project Specific Learning Outcomes:

-***Apply*** *learning outcomes 1-4 to a problem specific to your own research or one of the following preferential projects in power engineering M&S:*

› M&S of power system components for positive sequence simulation in the OpenIPSL library (see list of potential models herein: https://github.com/OpenIPSL/OpenIPSL/projects

› Mixed positive sequence and three-phase models for power electronic-based components (e.g. VSC-HVDC, FACTS, Battery Energy Storage, etc.)

› Power electronic systems for traction, e.g. automotive applications, aerospace, etc.

- ***Or, Apply*** *learning outcomes 1-4 to a problem specific to your own research or one of the following preferential projects in multi-domain simulation:*

› Multi-domain M&S of power systems and fuel cell energy sources.

› Multi-domain M&S of power systems and hydro-power systems.

› Multi-domain M&S of power systems and Rankine Cycle steam turbines.

-***Or, Apply*** *learning outcomes 5-6 to a problem specific to your own research or one of the following preferential projects in cyber-physical systems simulation:*

› Interface simulation outputs from the OpenIPSL pseudo-PMU model to TCP using the Modelica Device library.

› Control design, coding and simulation for the 6-DOF arm robot using the Modelica Arduino library.

› Model PMUs using timed clocked sensors with different loop rates using the Modelica Synchronous library.

› Develop a hardware-in-the-loop simulator using the Raspberry Pi and an Arduino.

Required Knowledge

Knowledge on the forllowing areas is mandatory:

-Differential Equations

-Linear Algebra

Knowledge and skills in the following areas are recommended

-Familiarity with computer programming languages (e.g. Python, MATLAB/Simulink)

-Control Systems Engineering

-Signals and Systems

Reference Texts	**Course textbooks (required/mandatory)** -P. Fritzson, *Principles of Object-Oriented Modeling and Simulation with Modelica 3.3: A Cyber-Physical Approach.* Wiley-IEEE Press, 2014. ISBN: 978-1-118-85912-4. -(Free-of-cost) Michael M. Tiller, *Modelica by Example*. E-book. On-line: http://book.xogeny.com -Dymola User Manuals (Digital version is available with the software under ./Help/Documentation/) **Required Embedded Platform** -Arduino Uno It is possible to find many options online, the following two are just suggestions: -Official Arduino Starter Kit: https://store.arduino.cc/usa/arduino-starter-kit **Other Suggested Books and References:** -P. Fritzson, *Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica.* Wiley-IEEE Press, 2011. ISBN: 978-1-118-01068-6. -Francois E. Cellier and Ernesto Kofman, "Continuous System Simulation," Springer-Verlag New York, Inc. Secaucus, NJ, USA, 2006. ISBN:0387261028 **Computing Tools** -Dymola – licenses to be provided by KAUST. -OpenModelica – open source software: http://openmodelica.org/ -Python, MATLAB/Simulink (campus license from KAUST). -FMI Toolbox for MATLAB - to be provided by KAUST. -Anaconda: Python and Jupyter Notebooks, open source software: https://www.anaconda.com
Method of evaluation	**50.00**% - Course Project(s) **10.00**% - Others - Please specify **40.00**% - Homework /Assignments
Nature of the assignments	-Homework Assigments consist of computer-based excercises using Dymola, to be carried out individually. -Lab reports consists on the documentation of the experiments carried out, one example and one open problem, the open problem is to be carried out individually. -Final project consists of a student proposed project where the course intended learning outcomes can be assessed independently.

Course Policies

Grading Criteria / Policy

-*Quantitative assessment*

- › 16 Homework/Workshops: 40% of the grade, all weighted equally.
- › 2 Lab Reports: 10 points, 10%
- › 1 Final Project: 50%.
- › Total: 100 points

-*Letter grading criteria:* following individual achievement of learning outcomes, the criteria is:

- › A/A- high competency achieving the learning outcomes;
- › B+/B/B- good competency;
- › C+/C/C- marginal competency.

-Final Grade: The result from your quantitative assessment will be used as a **guideline** in determining your final grade, using the table below. The letter grading criteria will be applied considering your performance, in particular, in the Final project, see “Project Specific Learning Outcomes,” above.

-Quantitative Assessment Guideline Table

Letter Grade	Percent Grade	Letter Grade	Percent Grade
A	93 – 100	C+	77 – 79
A-	90 – 92	C	73 – 76
B+	87 – 89	C-	70 – 72
B	83 – 86	D+	67 – 69
B-	80 – 82	D	65 – 66
		E/F	Below 65

Homework/Workshop and Lab Assignments Policy

-All homework/lab assignments and projects will be graded by the instructor or TA.

-Credits are given for partially completed assignments.

-Homework submission via LMS/Blackboard, write-up, computer-based models and code used to solve the problems must be provided in a .zip file.

-Late homework submission requires the instructor’s permission and valid justification, NO late homework are accepted without prior permission.

Attendance policy

All students are expected to attend classes unless previously excused.

Other Policies

-**Extra credit policy:** Challenging yourself in this course and showing your own initiative in the solution of the homework/lab problems will be highly valued, and rewarded following the policy in the sequel:

-Extra credits for exceptional and creative work in the approach to solve problems using computer-based modeling languages, and computer tools; at the instructor's discretion.

-**Mobile/Electronic Devices:**

› All mobile devices (cell/smart phones, etc.) must be stored securely away during lecture and are not be used unless specifically directed otherwise by the instructor.

› Use of (or ANY interaction with) a mobile device during without explicit permission of the instructor will be interpreted as the illicit transfer of exam data, will be considered an act of cheating and will be treated as such.

› When working with computer problems in class, messaging/email or similar applications should not be active in your computer, only those used in class are allowed.

Additional Information	**Academic integrity** Student-teacher relationships are built on trust. For example, students must trust that teachers have made appropriate decisions about the structure and content of the courses they teach, and teachers must trust that the assignments that students turn in are their own. Acts that violate this trust undermine the educational process. KAUST's Student Handbook defines various forms of Prohibited Conduct (Cheating, plagiarism, etc., link) and you should make yourself familiar with these. In this class, all assignments that are turned in for a grade must represent the student's own work. In cases where help was received, or teamwork was allowed, a notation on the assignment should indicate your collaboration. Submission of any assignment that is in violation of this policy may result in a penalty of: A grade of zero will be given when the first violation is detected. If there is a subsequent infraction the student will receive a grade of F for the course. Violations may also be reported to the appropriate Dean of Graduate Affairs. If you have any questions concerning this policy before submitting an assignment, please ask for clarification.

Tentative Course Schedule

(Time, topic/emphasis & resources)

Week	Lectures	Topic
1	Wed 06/19/2019 Thu 06/20/2019	Wed 06/19 Session 00: -Administrative Matters -Introduction to the Course Session 01: -Introduction to Modelica & Dymola -Readings: Cellier Ch. 1, Fritzson Ch. 1, 19 -Assignment: HW 01. Thu 06/20 Session 02: -Topic: Building Object-Oriented Graphical Models in Dymola -Readings: Fritzson Ch. 12 -Assignment: HW 02. Session 03: -Topic: Simulation and Post-Processing -Readings: Cellier Ch. 2-3, Fritzson Ch. 17 -Assignment: HW 03.
2	Wed 06/26/2019 Thu 06/27/2019	Session 04: -Topic: System Models and System-Wide Simulation Configuration -Readings: Fritzson Ch. 12 -Assignment: HW 04. Session 05: -Topic: Developing Models using the Modelica Language -Readings: Fritzson Ch. 5, 8, 9 -Assignment: HW 05.
3	Wed 07/03/2019 Thu 07/04/2019	Session 06 - a: -Topic: Understanding Equation-Based Modeling -Readings: Fritzson Ch. 5, 8, 18 (pp. 1001 – 1016), Cellier Ch. 7 -Assignment: HW 6a. Session 06 - b: -Topic: Graphical Annotations, Interfaces and Documentation in Dymola -Readings: Fritzson Ch. 11 -Assignment: HW 6b. Session 07: -Topic: Building Models using the Modelica Standard Library -Readings: Fritzson Ch. 16.1-16.8 -Assignment: HW 7.
4	Wed 07/10/2019 Thu 07/11/2019	Session 08: -Topic: System Models using the MSL and Intro to Reactive/Hybrid Systems -Readings: Fritzson Ch. 16.9, 16.11 - 16.13 -Assignment: HW 8. CPS Lab. 1: -Using The Modelica Arduino Library and the Arduino Starter Kit -Readings: Arduino Starter Kit Booklet - Chapters 1, 2, and # of your assigned project.

5	Wed 07/17/2019 Thu 07/18/2019	Session 09: -Topic: Development, Debugging and Identifying Numerical Issues -Readings: Fritzson Ch. 18.3, Cellier Ch. 7, 8 -Assignment: HW9 Session 10: -Topic: Reusable Modeling – Model Architectures, Templates and Interfaces -Readings: Fritzson Ch 12.4, Tiller (section on Architectures: https://mbe.modelica.university/components/architectures/) -Assignment: HW10. Session 11: -Topic: Model Variants and Data Management -Readings: Tiller (section on Architectures: https://mbe.modelica.university/components/architectures/) -Assignment: HW 11.
6	Wed 07/24/2019 Thu 07/25/2019	Session 12: -Topic: Discontinuous and Hybrid System Modeling Principles and Specialized Operators for Time and State Event Handling -Readings: Cellier Ch. 9, Fritzson Ch. 13 -Assignment: HW 12. Session 13: -Topic: Workflow Automation and Scripting -Readings: Fritzson Ch. Appendix E, pp. 1141 - 1148 -Assignment: HW 13. Session 14: -Topic: Integrating Dymola with Other Tools and the FMI Standard for Model-Exchange and Co-Simulation -Readings: Fritzson Appendix G, pp. 1159 - 1168 -Assignment: HW 14.
7	Wed 07/31/2019 Thu 08/01/2019	Wed, Session 15: -Topic: Real-Time Simulation Principles and Applications -Readings: Cellier Ch. 10 -Assignment: HW 15. Thu, CPS Lab. 2: -Real-Time Hardware-in-the-Loop Simulation -Readings: Manuals and materials from robot arm kit. ModelPlug library and SystemModeler Tutorial.
8	Wed 08/07/2019 Thu 08/08/2019	Semester ends

Note

The instructor reserves the right to make changes to this syllabus as necessary.