Introduction to Cyber-physical Systems (CMPE 142)
Fall 2014

Instructor Information:
Prof. Ricardo G. Sanfelice
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General Information:

- Meetings: Tuesday and Thursday 4pm to 5:45pm (10/02/14 - 12/12/14), J. Baskin Engr 372
- Office hours: T 6:00pm to 7:00 pm and Th 3:00pm to 4:00 pm (both at E2-321)

Course Description:

Cyber-physical systems combine digital and analog devices, interfaces, networks, computer systems, and the like with the natural and man-made physical world. The inherent interconnected and heterogeneous combination of behaviors in these systems makes their analysis and design a challenging task. Safety and reliability specifications imposed in cyber-physical applications, which are typically translated into stringent robustness standards, aggravate the matter. Unfortunately, state-of-the-art tools for system analysis and design cannot cope with the intrinsic complexity in cyber-physical systems. Tools suitable for analysis and design of cyber-physical systems must allow a combination of physical or continuous dynamics and the cyber or computational components, as well as handle a variety of types of perturbations, such as exogenous disturbances, time delays, and system failures.

This course provides an introduction to modeling and analysis of cyber-physical systems. After an introduction to the class of systems of interest via examples in engineering and science, several models of continuous-time systems and discrete-time systems are introduced. The main focus is on models in terms of differential equations for the modeling of physical process. Finite state machines and stateflow are introduced and combined with the physical models. Applications of the resulting models for modeling and analysis of embedded systems are discussed. With this basic background, the more advanced timed automata and hybrid automata models are introduced. Then, linear temporal logic, which is the main tool taught in this class, is introduced and applied to specify the desired system behavior. Tools for analytical study and numerical verification of the satisfaction of linear temporal logic formulae are presented and discussed in numerous applications.

Catalog Description:

Basic concepts and tools for the study of cyber-physical systems, including modeling and analysis tools for continuous-time and discrete-time systems, finite state machines, stateflow, timed and hybrid automata, concurrency, invariants, linear temporal logic, verification, and numerical simulation. Students will be guided on methods for simulation and encouraged to apply them to several applications.

Topics:

Introduction to continuous-time systems; Modeling of physical processes; Linear time-invariant systems; Numerical simulation of differential equations; Introduction to discrete-time systems and return maps; Finite state machines; Event triggered systems; Stateflow; Timed automata; Hybrid automata; Concurrency; Invariants; Linear temporal logic; Introduction to verification.

Prerequisites:

The course is self contained. Students are expected to have basic background on logic circuits (CMPE 100 or equivalent), programming (CMPE 13 or equivalent), mathematical modeling of dynamical systems (CMPE 8 recommended), differential equations, linear algebra, and basic calculus. Knowledge of Matlab/Simulink will be useful.

Mandatory course requirements:

CMPE 100: Logic Design

CMPE 13: Computer Systems and C Programming

Suggested additional courses:

CMPE 8: Robot Automation: Intelligence through Feedback Control

Structure and Grading Scheme:

- Homework will account for **20%** of final grade. **Schedule**: ≈ one HW every other week.
- Quizz, will account for **10%** of final grade. **Schedule**: announced 1.5 days in advance.
- Midterm, **20%** of final grade. **Schedule**: 4pm on 11/04, in class.
- Final, **30%** of final grade. **Schedule**: 4pm on 12/15, in class.
- Presentations and project report, **20%** of final grade. **Schedule**: Presentations on 12/11, in class; final project report due 5pm on 12/17.

Additional Useful Information:

- Email will be the preferred way to communicate. Please check your email frequently for announcements. An immediate response from the instructor is not guaranteed, but you should expect to get one within 24hs on weekdays.
- There will be no make-ups for any exam. If you are unable to take a scheduled exam due to health reasons, you must notify the instructor prior to the beginning of the exam. If you will be absent to an exam due to a death (or life-threatening illness) in your family, similar advance notification and subsequent documentation will be required. Students absent from an exam for one of the above reasons will be assigned a grade reflecting performance on homework and previous/future exams. Students missing exams under conditions not discussed above will normally be awarded a zero.
- Exams are closed notes and books.

- Use of cellphones, laptops, tablets and the like is not permitted in class.
- The instructor holds the copyright for lectures and course materials, and these materials are made available for personal use by students. Students may not distribute or reproduce the materials for commercial purposes without the instructor?s express written consent.

References:

- **Main reference** : Instructor's lecture notes and handouts.
- E. A. Lee and S. A. Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, Lulu.com, First Edition, Jan 2013.
  Online: `http://leeseshia.org/releases/LeeSeshia_DigitalV1_08.pdf`
- Lectures notes by A. Podelski and S. Bogomolov:
  `http://swt.informatik.uni-freiburg.de/teaching/SS2012/cps-hm`