CS 556: Cyber-Physical Systems: Languages and Systems

Course Description

As the advance of computer hardware, embedded devices, and network technology, applications that involve both cyber and physical components are emerging, ranging from smart automobile, to automated traffic control systems. Different from general-purpose and traditional computer applications, cyber-physical systems have both continuous and discrete components, hence require new methodologies to integrate traditional continuous control theory/systems with traditional discrete software systems. The focus of this class is to discuss and understand the challenges in emerging cyber-physical systems and to explore possible solutions from the perspectives of system specification; system modeling; programming languages; system designs; and software engineering.

The course will start with a review of necessary background. In particular, it will review traditional distributed systems, open systems, real-time systems, real-time embedded systems, control theory, and emerging cyber-physical systems; discuss differences among these systems; and identify, in general, the challenges in designing and developing cyber-physical systems. The course then will focus on addressing challenges and discussing possible solutions from languages and systems perspectives, and focus on discussing different system modelings and analysis and design of cyber-physical systems. New and emerging topics in both theoretical CPS research and CPS applications will be presented as well.

Approximately two-thirds of the course will be devoted to basic concepts and techniques, and one-third will be devoted to the discussion of current research challenges in the related topics.

Course Objective

To study the basic concepts, requirements, principles and techniques in emerging cyber-physical systems. The focus is on the differences between general-purpose computing and cyber-physical systems, how the temporal requirements, integration of continuous and discrete components are realized through specification, system modeling, real-time scheduling, and real-time resource management, and how the cyber-physical system's safety properties are verified.

The course also aims to provide students of different disciplinary background with necessary knowledge to understand the fundamentals of cyber-

physical systems and being able to contribute to the development of new cyber-physical system applications; and stimulate research interest in this area.

Course Syllabus

The topics to be covered in the course include the following:

- Overview of distributed systems, open systems, real-time systems, and real-time embedded systems
- Understand cyber-physical systems and the fundamental differences from traditional systems
- System modeling
  - continuous systems
  - discrete systems
  - hybrid systems
  - system specification and verification
- Resource management for cyber-physical systems
  - resource scheduling
  - temperature and power management
  - real-time communication
- Programming Languages
  - Overview
  - The notion of time
  - Programming timeouts
  - Specifying timing requirements
  - Language support for temporal scopes
  - Constraint-oriented specification style for time-dependent behaviors
- Other
  - Software Engineering specific issues in design and development of cyber-physical systems.

Course Material

Reference Text Book: There is no mandated textbook. Recommended books are:

- J, Liu, Real Time Systems, ISBN-10: 0130996513 — ISBN-13: 978- 0130996510
- P. Tabuada, Verification and control of hybrid systems: a symbolic approach, Springer-Verlag 2009
- J. Lygeros, Lecture notes on hybrid systems, 2006
- C. Cassandras, S. Lafortune: Introduction to Discrete Event Systems, Springer 2007
- A.J. van der Schaft, J.M. Schumacher, An Introduction to hybrid dynamical systems, Lecture Notes in Control and Information Sciences, Vol. 251, Springer-Verlag, London, 2000.
- D. Liberzon, Switching in systems and control, Birkhauser, 2003
- E. A. Lee, P. Varaiya, Structure and Interpretation of Signals and Systems, 2002
- Constance Heitmeyer and Dino Mandrioli, Formal methods for real-time computing, Wiley publisher
- TinyOS programming, By P Levis

Research papers: Research papers in the area will be provided.