Cyber-Physical Systems

Introduction

ICEN 553/453– Fall 2018

Prof. Dola Saha

Introductions

- Instructor
  - Prof. Dola Saha, PhD University of Colorado Boulder
  - http://www.albany.edu/faculty/dsaha/
  - https://www.albany.edu/wwwres/facultyresearch/mesalabs/
  - dsaha@albany.edu

- Students

Information

- Course Website:
  - https://www.albany.edu/faculty/dsaha/teach/2018Fall_CEN553/2018Fall_CEN553.html
- Blackboard:
  - https://blackboard.albany.edu/

Course Website	Blackboard
Lecture Slides	Lab Assignments / Pre-Lab
Class Calendar / Schedule	Homework Assignments / Submission / Solution
Other Information	Announcements
	Grades

Office Hours

Instructor
LI 89B (Will soon change to LI 88B)
Tuesday – 12:00-1:00pm
Thursday – 12:00-1:00pm
By appointment

Pre-Requisite

- ICEN 370: Digital Signal Processing
- ICEN 333: Programming at the Hardware Software Interface
- The students are expected to be comfortable in
  - Unix/Linux environment
  - Circuits

Textbooks

- Required:
  - Edward A. Lee and Sanjit A. Seshia, "Introduction to Embedded Systems, A Cyber-Physical Systems Approach", Second Edition, MIT Press, ISBN 978-0-262-53381-2, 2017, available for download [http://leeseshia.org/]
- Highly Recommended:
  - Derek Molloy, "Exploring Raspberry Pi: Interfacing to the Real World with Embedded Linux", Wiley, ISBN 978-1-119-18868-1, 2016.
- Reference:
  - Rajeev Alur, "Principles of Cyber-Physical Systems", MIT Press
  - Danda B. Rawat, Joel J.P.C. Rodrigues, Ivan Stojmenovic, "Cyber-Physical Systems: From Theory to Practice", CRC Press

Slides in this course will be taken from these books.

Assignments & Grading

- Assignments
  - No late assignments will be accepted.
  - All assignments are due by 11:59PM on the due date in Blackboard.
  - Re-grading requests will be considered up to 5 business days after posting the grades for the corresponding assignment.
- Grading
  - Labs (Pre and post-completion) - 15%
  - Homeworks - 15%
  - Midterm - 20%
  - Final Exam - 20%
  - Project Proposal - 10%
  - Final Project - 20%
    - [Model: 20%, Design - 20%, Analysis - 20%, Written Report - 20%, Final Presentation - 20%]

Components

- About 4 homeworks
- About 4-5 Lab Assignments
- Midterm – Written, closed book
- Final – Written, closed book
- Project (details in later slides)

Lab

- Hardware:
  - Raspberry Pi Kit (Checkout from Deneen Rogers – Li 84A)
  - Use Lab Manual to setup Headless Raspberry Pi
- Software:
  - Bash script, Python and C/C++ in Raspbian OS

Project

- This is not a research project
- Expected to use model, design and analysis (not just design)
- Teams of 2 people (recommended to not work alone)
- Discuss with instructor for technical plan with realistic timelines

Project Hardware

- Well chosen hardware
  - Instructor will spend $30 per team to choose the components
- Add Sensors and Actuators with Raspberry Pi
- Available in Instructor's Lab
  - Sense HAT with Raspberry Pi
  - Myo Gesture Control Armband
  - Intel Aero Drone
  - NAVIO Autopilot HAT for Raspberry Pi

Project Ideas

- https://www.raspberrypi.org/magpi/
- https://blog.adafruit.com/category/raspberry-pi/
- http://iccps.acm.org/2019/ - Look at papers of previous years to get inspiration

Grading Scale

- A: 100-95 points A-: 94-90 points
- B+: 89-87 points B: 86-84 points B-: 83-80 points
- C+: 79-77 points C: 76-73 points C-: 72-70 points
- D+: 69-67 points D: 66-63 points D-: 62-60 points
- E: 59 points and below

Academic Integrity

- Undergraduate Academic Regulations
  - http://www.albany.edu/undergraduate_bulletin/regulations.html
- Academic Dishonesty
  - Plagiarism, Cheating on examinations, unauthorized collaboration, etc.
- Practicing Academic Integrity
  - Citation
- Penalties for Violation
  - Zero in the assignment, lowering grade, failing grade, VAIR will be submitted

What is Plagiarism?

- Getting help from the Internet and not cite it
- Asking someone else to write the code for you
- Copying your friend's code – both the students are involved in plagiarism

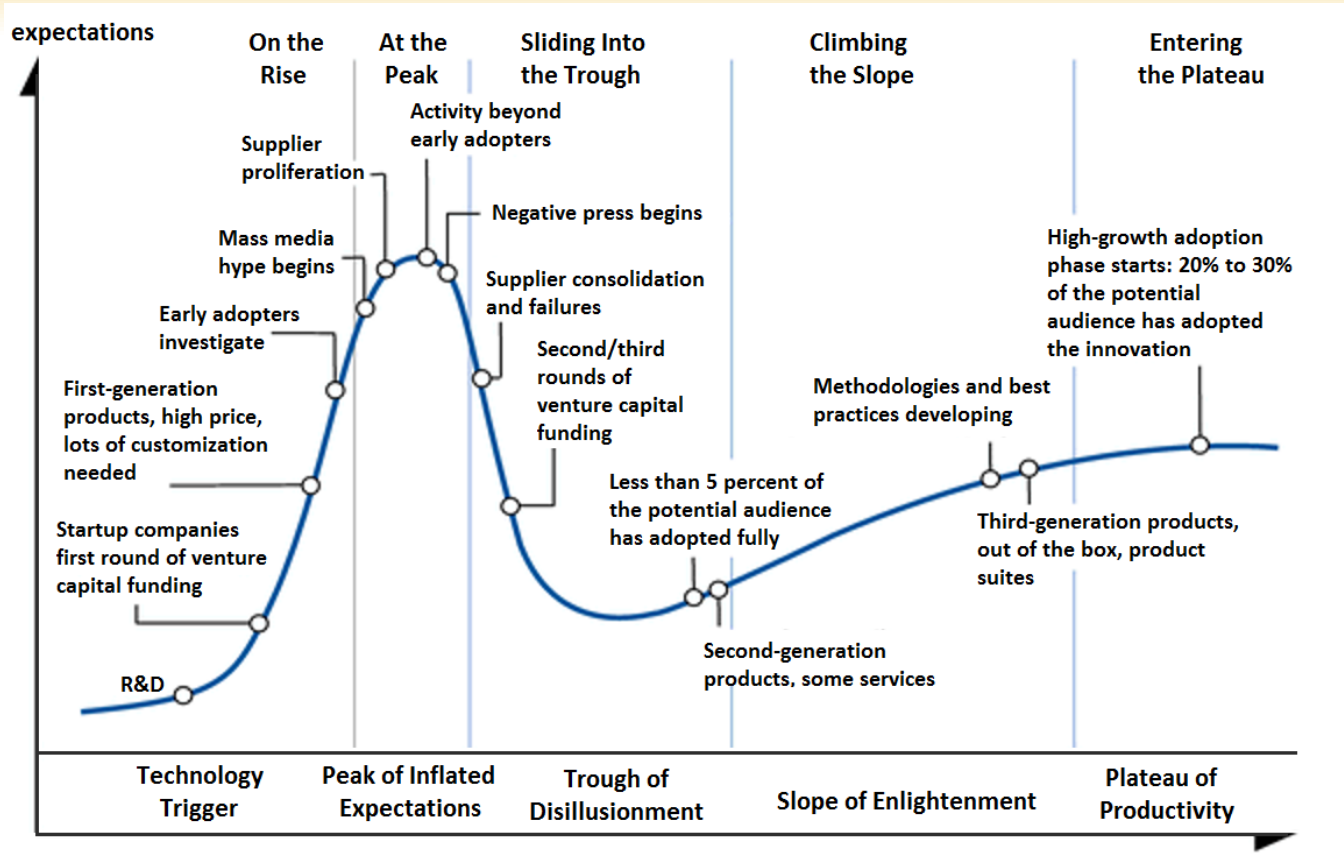
In Class Decorum

- No use of phones
- No use of Computers / laptops
- Computers will be used only when directed in the class
- DO NOT browse random things in class
- No crosstalk
- No Food/Drink
- Raise hand to ask questions

Why this course?

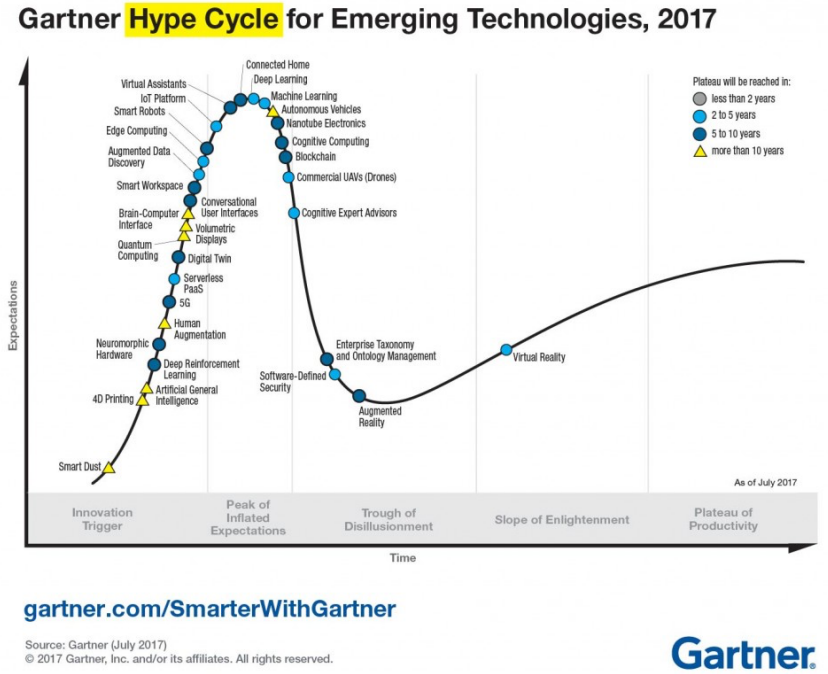
Hype Cycle

- gartner.com



Hype Cycle 2016, 2017

Source: Gartner (July 2016)



gartner.com/SmarterWithGartner

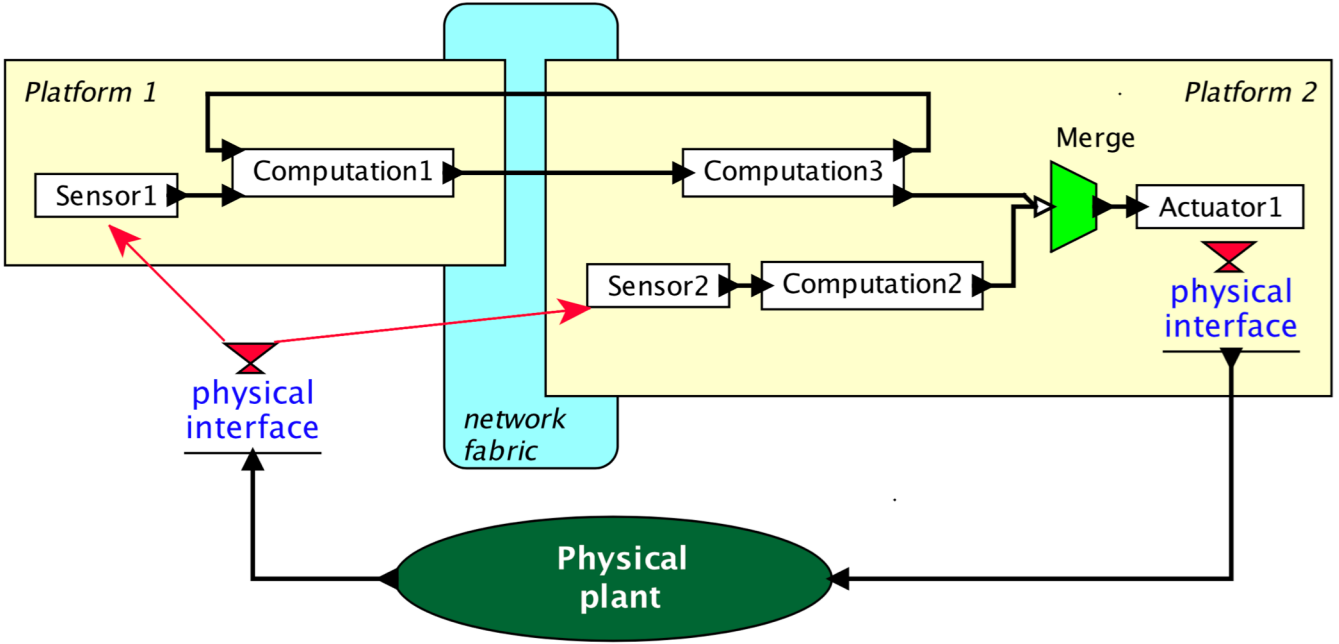
Gartner

2016

2017

About the Term

- The term “cyber-physical systems” emerged in 2006, coined by Helen Gill at the National Science Foundation in the US.



NSF's Definition of CPS

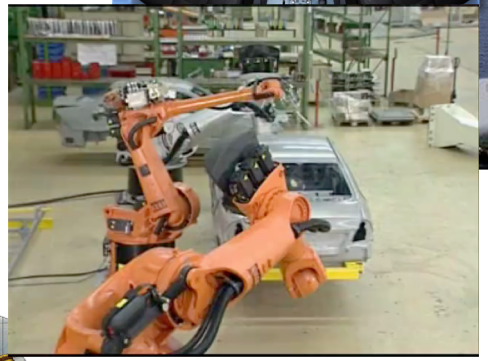
- Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the *seamless integration* of computation and physical components.
- Advances in CPS will *enable* capability, adaptability, scalability, resiliency, safety, security, and usability that will expand the horizons 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.

Application Domains – major societal impact

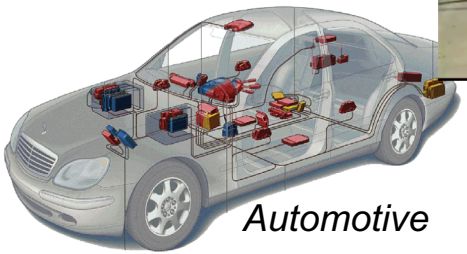
- Agriculture, Aeronautics, Building design, Civil infrastructure, energy, environmental quality, healthcare and personalized medicine, Manufacturing, and transportation.

CPS

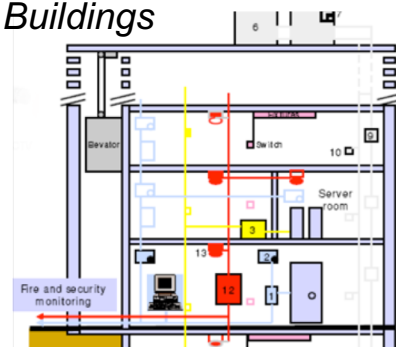
- Cyber + Physical
- Computation + Dynamics + Communication
- Security + Safety



Manufacturing



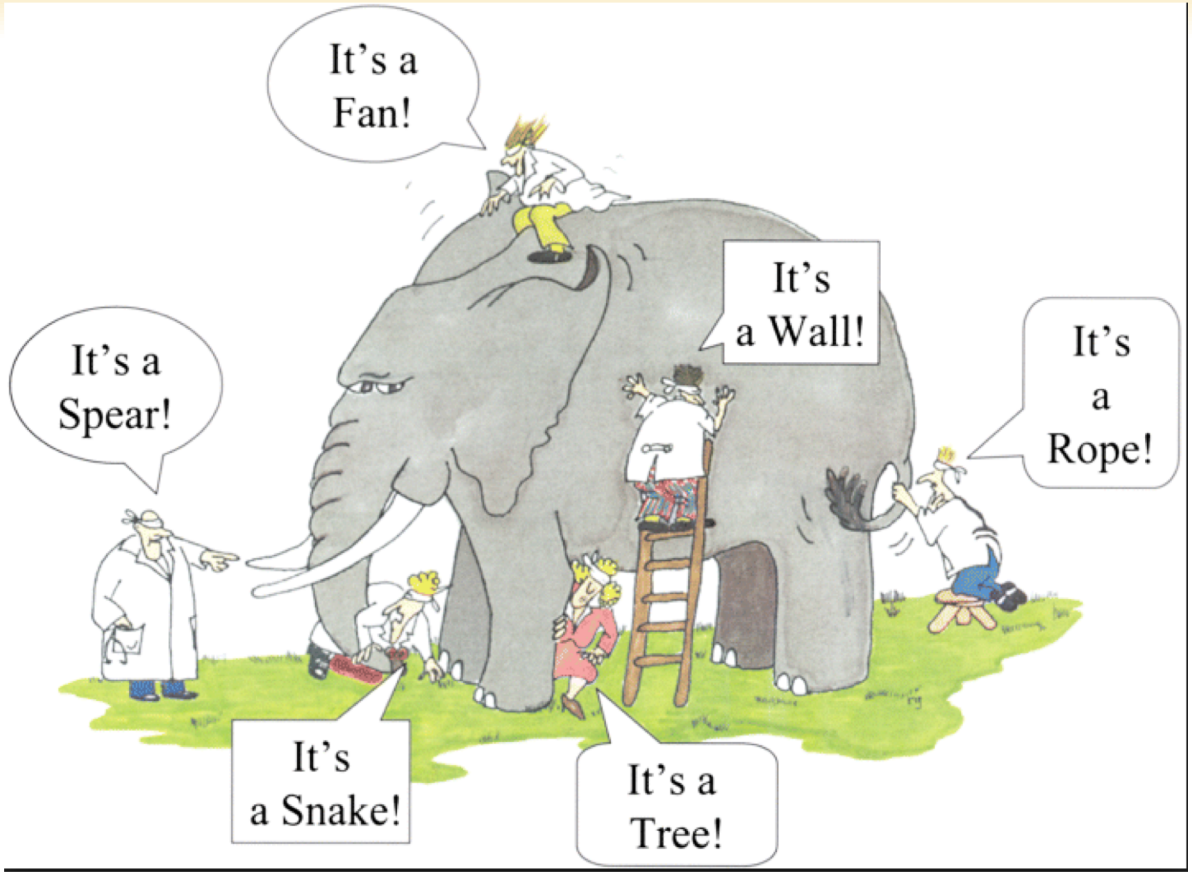
Automotive



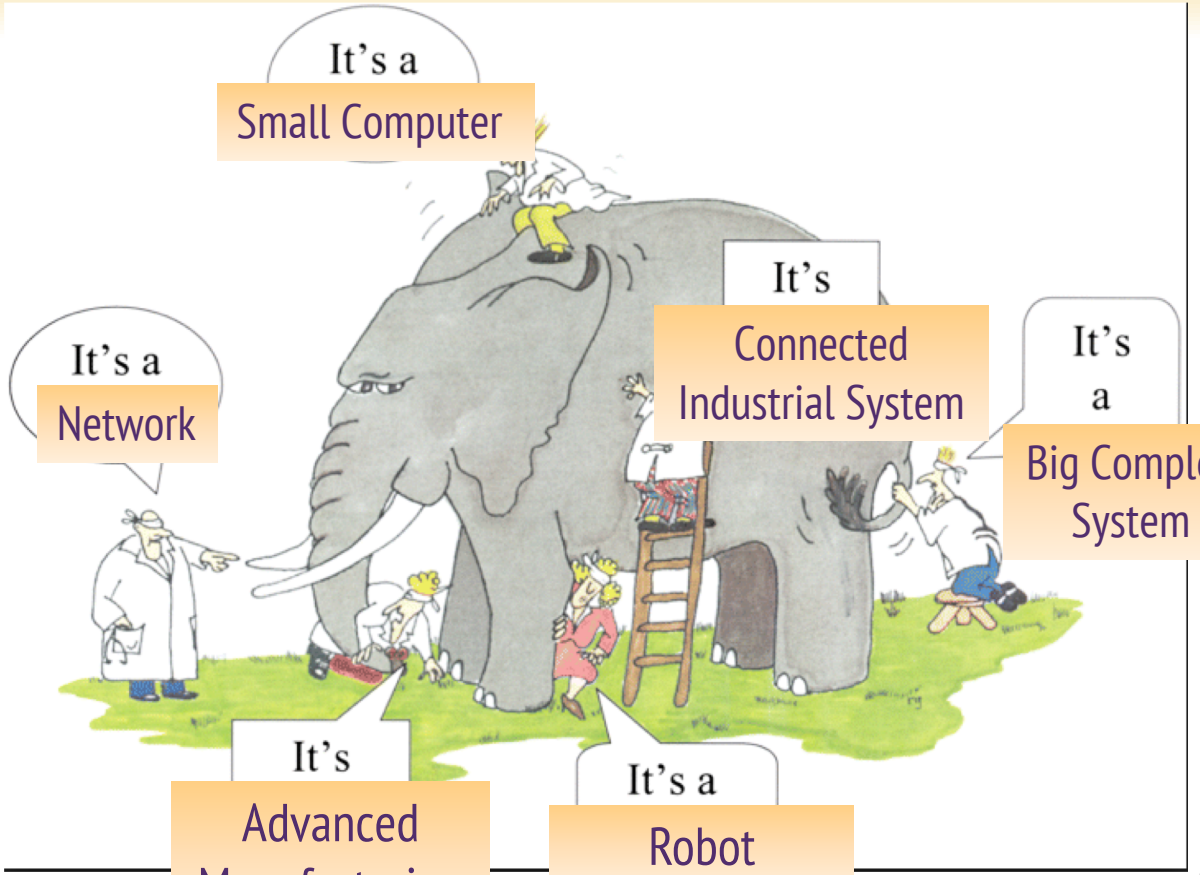
Contradictions in CPS

- Adaptability vs. Repeatability
- High connectivity vs. Security and Privacy
- High performance vs. Low Energy
- Asynchrony vs. Coordination/Cooperation
- Scalability vs. Reliability and Predictability
- Laws and Regulations vs. Technical Possibilities
- Economies of scale (cloud) vs. Locality (fog)
- Open vs. Proprietary
- Algorithms vs. Dynamics

Challenges of Working in a Multidisciplinary Area

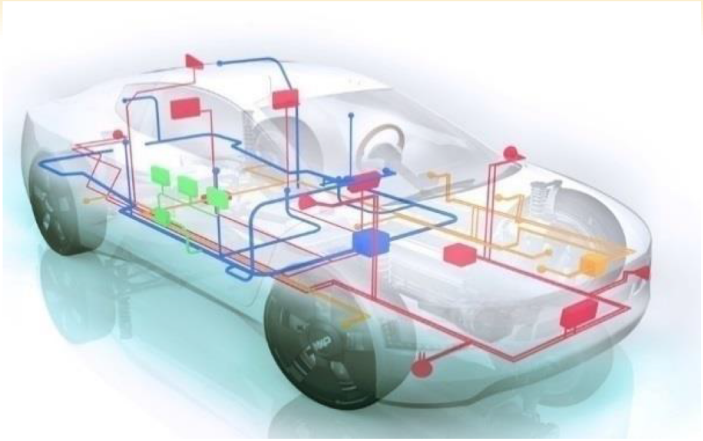


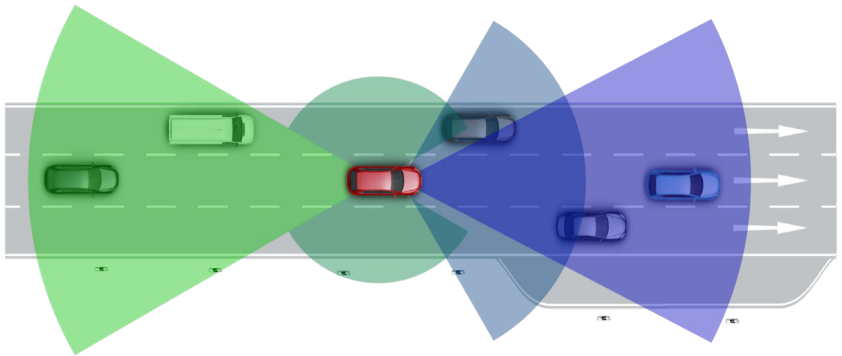
Challenges of Working in a Multidisciplinary Area



Automotive CPS

- Safer Transportation
- Reduced Emissions
- Smart Transportation
- Energy Efficiency
- Climate Change
- Human-Robot Collaboration

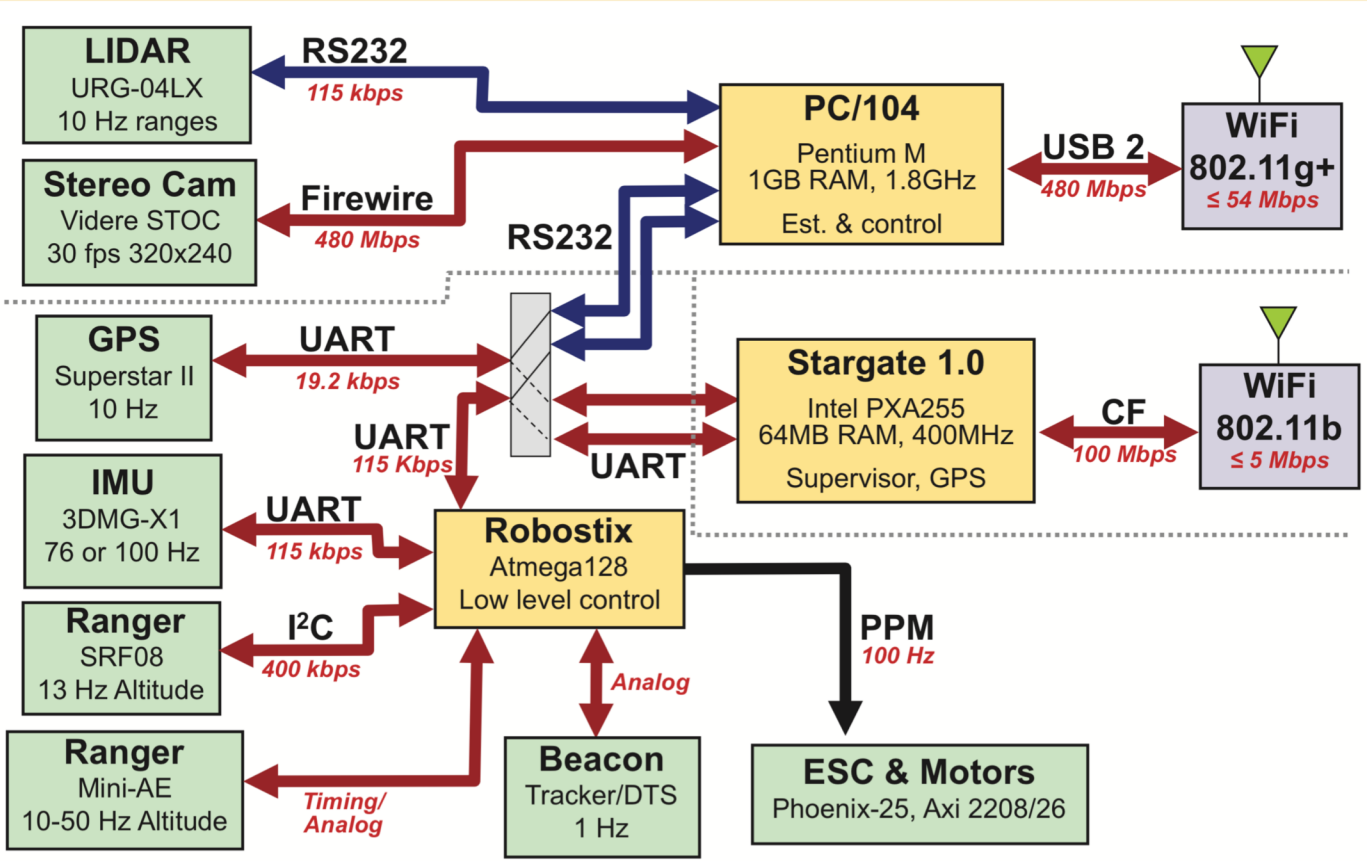




Example CPS System

- STARMAC Quadrotor Aircraft

STARMAC Design Block



What is this course about?

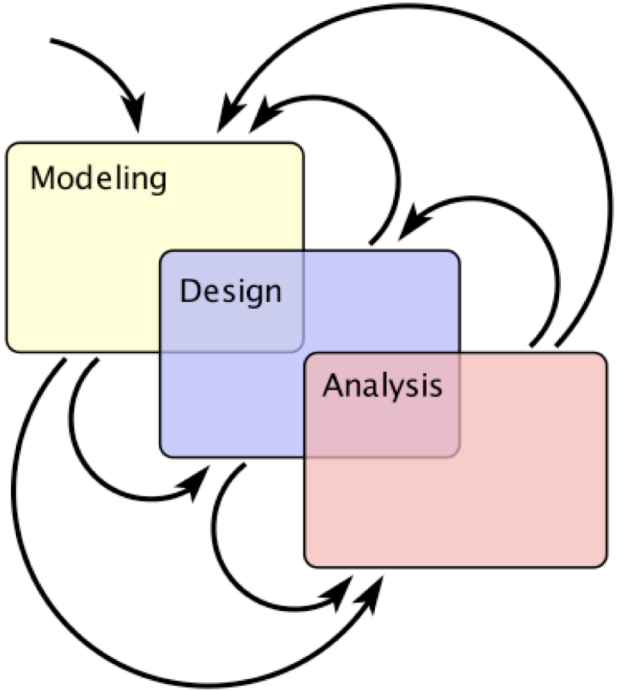
- A scientific structured approach to designing and implementing embedded systems
- Not just hacking and implementing
- Focus on model-based system design, on embedded hardware and software

Model, Design & Analysis

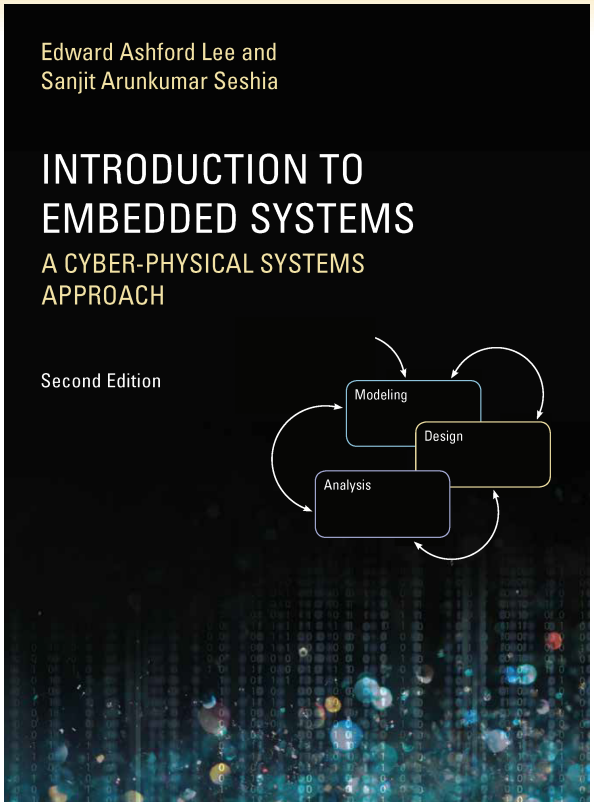
- ***Modeling*** is the process of gaining a deeper understanding of a system through imitation. Models specify **what** a system does.

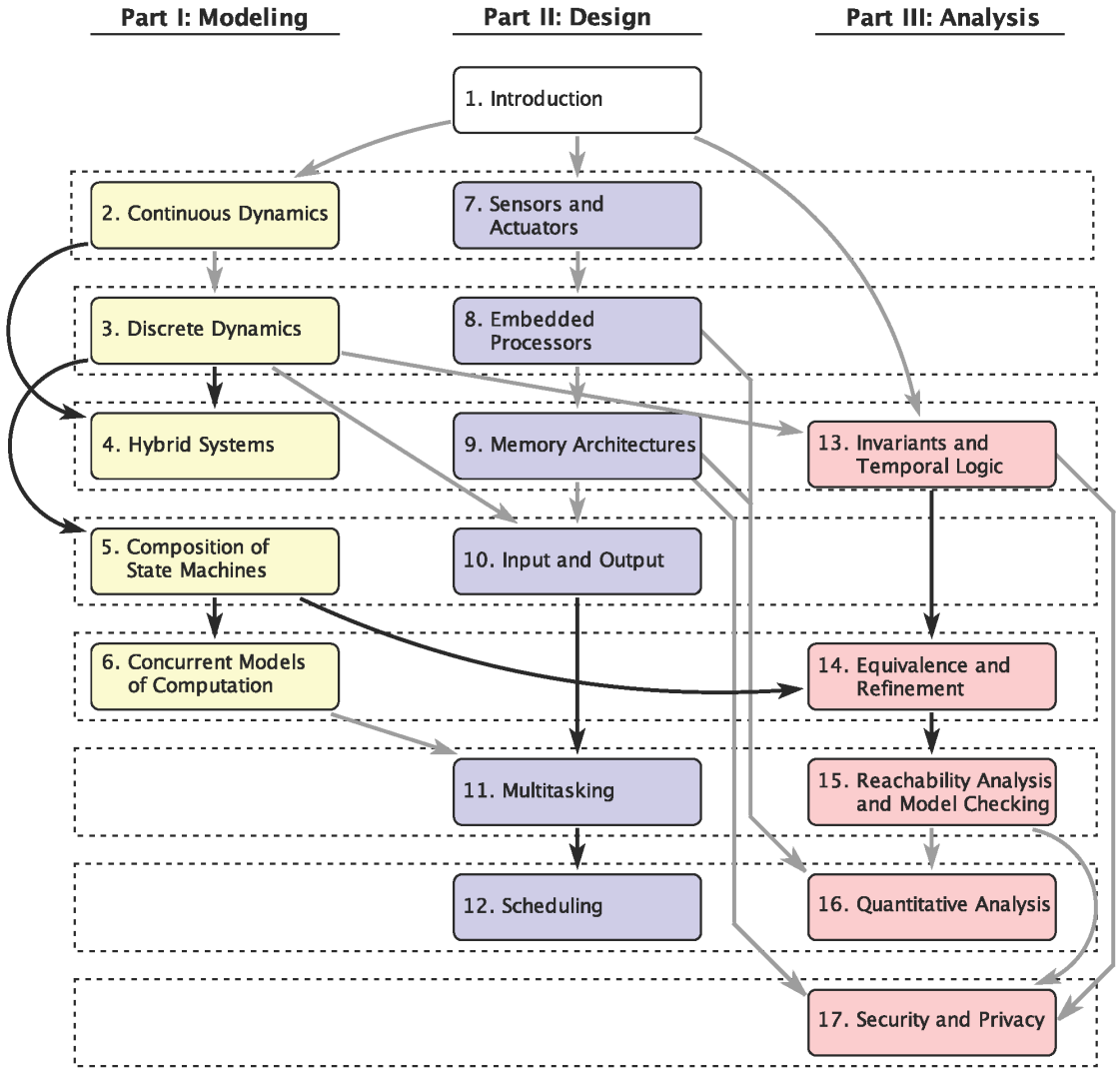
- ***Design*** is the structured creation of artifacts. It specifies **how** a system does what it does. This includes optimization.

- ***Analysis*** is the process of gaining a deeper understanding of a system through dissection. It specifies **why** a system does what it does (or fails to do what a model says it should do).



Textbook


Edward Ashford Lee and
Sanjit Arunkumar Seshia
INTRODUCTION TO
EMBEDDED SYSTEMS
A CYBER-PHYSICAL SYSTEMS
APPROACH
Second Edition
Modeling
Design
Analysis


Part I: Modeling
Part II: Design
Part III: Analysis
1. Introduction
2. Continuous Dynamics
7. Sensors and Actuators
3. Discrete Dynamics
8. Embedded Processors
4. Hybrid Systems
9. Memory Architectures
13. Invariants and Temporal Logic
5. Composition of State Machines
10. Input and Output
6. Concurrent Models of Computation
14. Equivalence and Refinement
11. Multitasking
15. Reachability Analysis and Model Checking
12. Scheduling
16. Quantitative Analysis
17. Security and Privacy

Course Calendar

- https://www.albany.edu/faculty/dsaha/teach/2018Fall_CEN553/2018Fall_CEN553.html