Cyber-Physical Systems

Introduction

IECE 553/453– Fall 2021

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
- Teaching Assistant
  - Xue Wei
  - xwei4@albany.edu
- Students (Identify your areas of interest)
  - Communications & Networking, Signal & Information Processing, Computer Engineering, Electronic Circuits & Systems

Students

Information

- Course Website:
  - https://www.albany.edu/faculty/dsaha/teach/2021Fall_ECE553/2021Fall_ECE553.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
Online: Zoom Link posted in Blackboard
Tuesday – 9:30-10:30am
Thursday – 9:30-10:30am
By appointment

Fall Back Plan for Online Mode

- Zoom link posted in Blackboard
  - For Lecture delivery
  - For Laboratory
  - Show your circuits using your camera

Pre-Requisite

- Programming at the Hardware Software Interface
- Signals & Systems
- 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

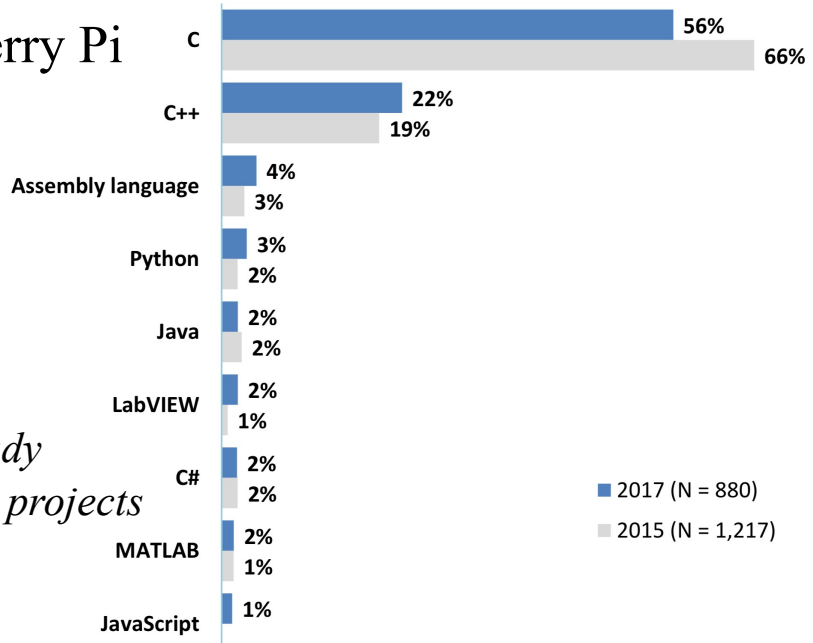
- Assignments
  - No late assignments will be accepted.
  - All assignments are due by 11:59PM on the due date in Blackboard.
  - Re-grading requests will be considered for up to 5 business days after posting the grades for the corresponding assignment.
- Grading
  - Labs (Pre and post-completion) - 10%
  - Homeworks - 15%
  - Midterm - 25%
  - Final Exam - 25%
  - Project Proposal - 2%
  - Midterm Project Assessment – 8%
  - Final Project - 15%
    - [Model: 20%, Design - 20%, Analysis - 20%, Written Report - 20%, Final Presentation - 20%]

Components

- About 4-6 homeworks
- Weekly Lab Assignments
- Midterm – Written, closed book
- Final – Written, closed book
  - **Dec 14: 1:00PM-3:00PM**
- Project (details in later slides)

Lab

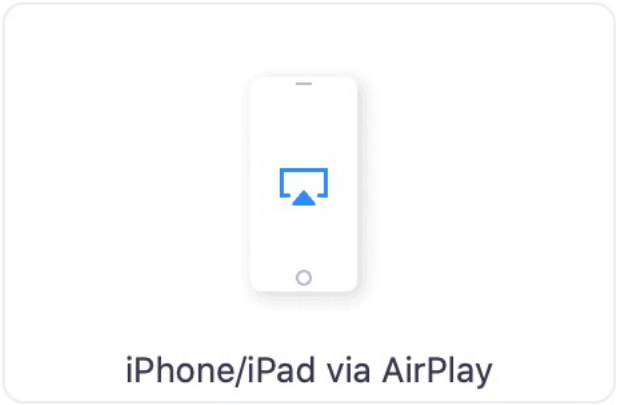
- Hardware:
  - Loan Raspberry Pi Kit
  - Purchase Sensor Kit (Adeept or Amazon)
  - Use Lab Manual to setup Headless Raspberry Pi
- Software:
  - Bash script, Python and C/C++
  - Raspberry Pi OS

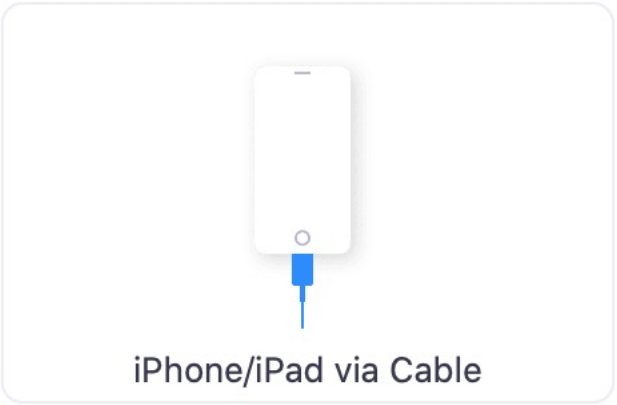


2017 Embedded Markets Study
Language used in embedded projects
eetimes

Share Phone Screen

- To show the circuit design, share phone screen
  - iPhone user (Share through Zoom)





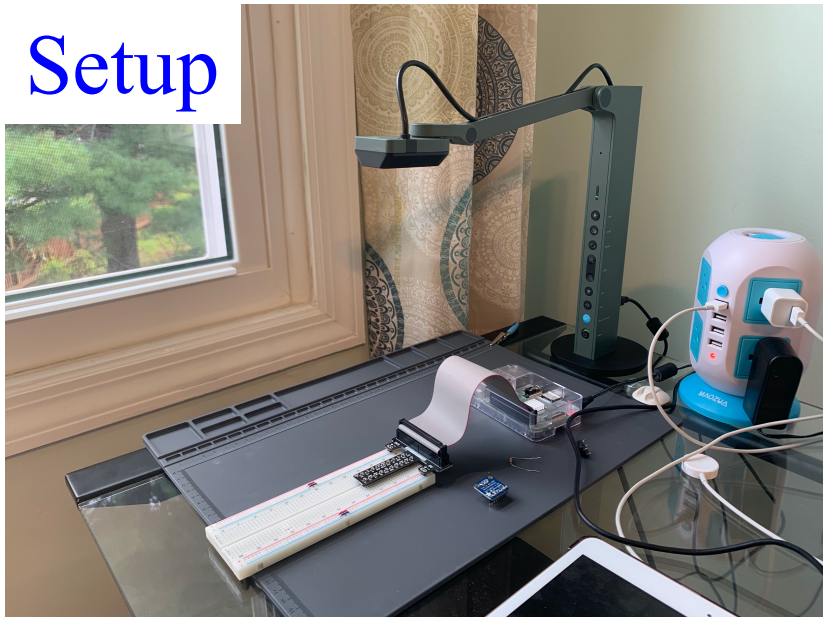
  - Android user (use DroidCam)

Required only as a fallback plan if the University needs to move completely online

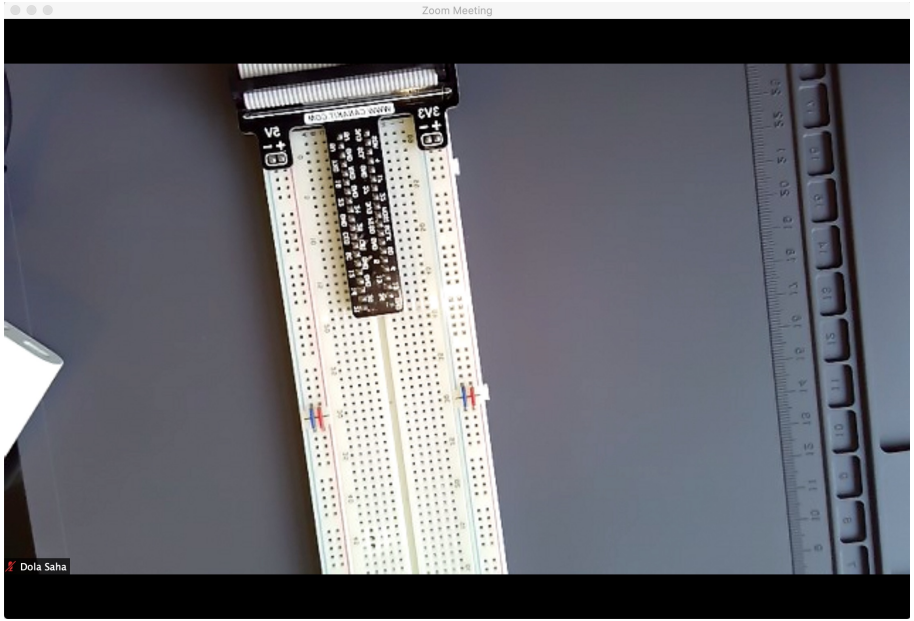
Lab and Lab Assignment

- Setup your phone to show the circuit before the lab begins

Setup



View in Zoom



Project

- This is not a research project
- Expected to use model, design and analysis (not just design)
- Discuss with instructor for technical plan with realistic timelines

Project Hardware

- Set of components from your lab kit

Project Ideas

- https://www.raspberrypi.org/magpi/
- https://blog.adafruit.com/category/raspberry-pi/

Project Samples

- Project Report
  - https://www.albany.edu/faculty/dsaha/teach/2020Fall_ECE553/resources/sample_project_report.pdf
- Project Presentation
  - https://www.albany.edu/faculty/dsaha/teach/2020Fall_ECE553/resources/sample_project_ppt.pdf

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

Difference between 453 and 553

- Extra /different problems in homework
- Extra /different problems in lab
- Extra /different problems in midterm
- Extra /different problems in finals

Academic Integrity

- Standards of Academic Integrity
  - https://www.albany.edu/studentconduct/27179.php
- 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
  - You can appeal to the department committee

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

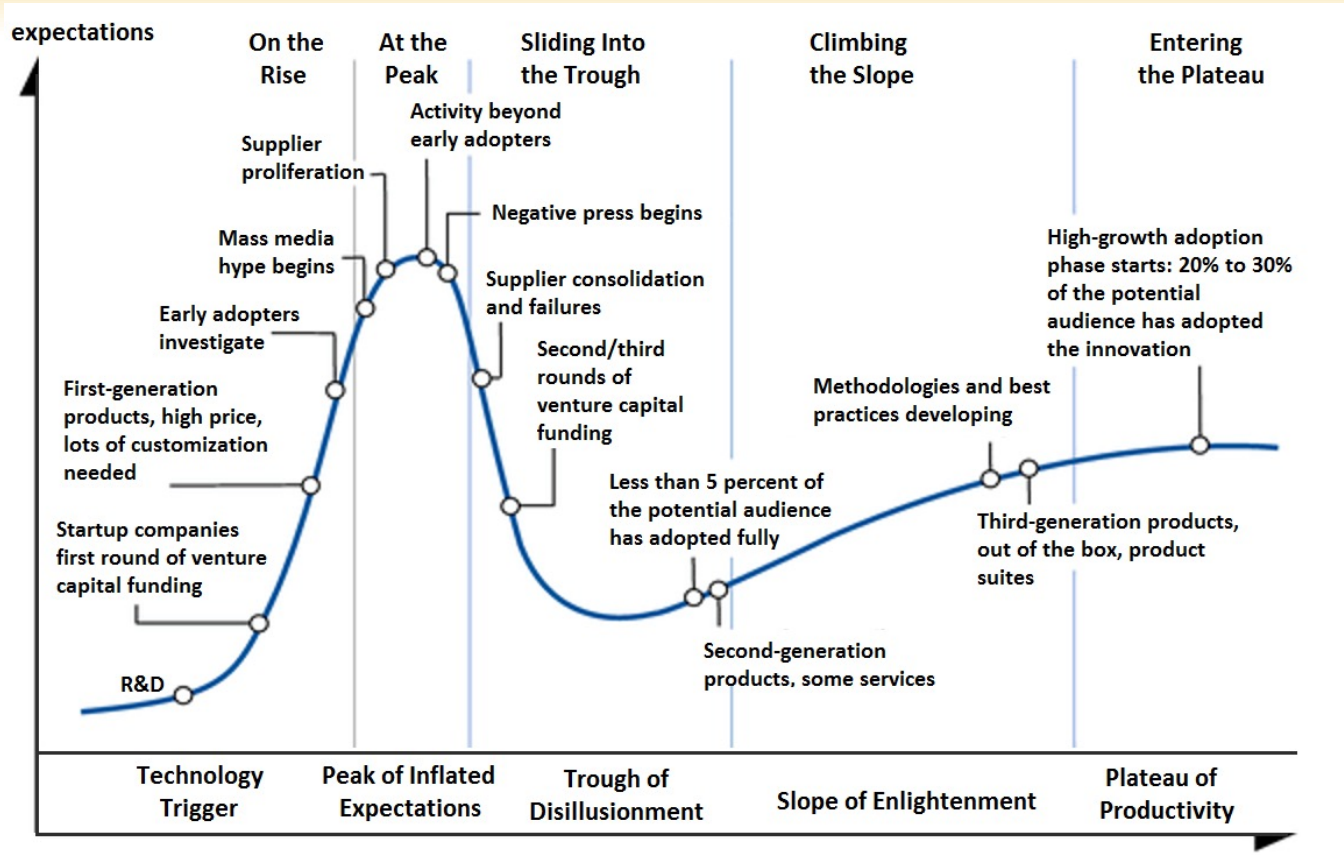
In Class Decorum

- **Mask** is required for both lecture and lab sessions **throughout the semester**
- No water or food in class
- No use of phones or laptops in class
- Computers will be used ONLY during lab session
- No crosstalk
- Attendance is not mandatory

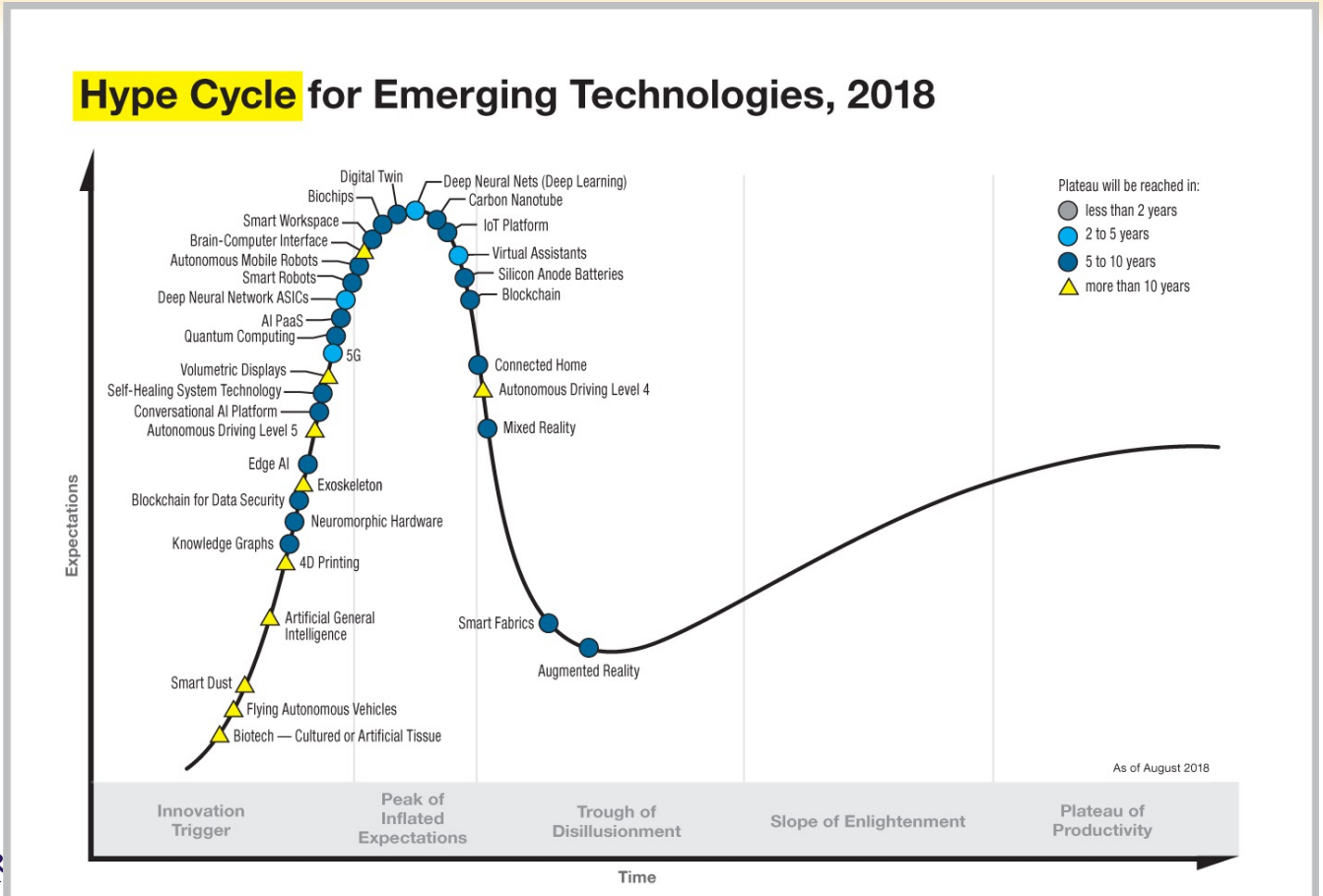
Why this course?

Hype Cycle

- gartner.com

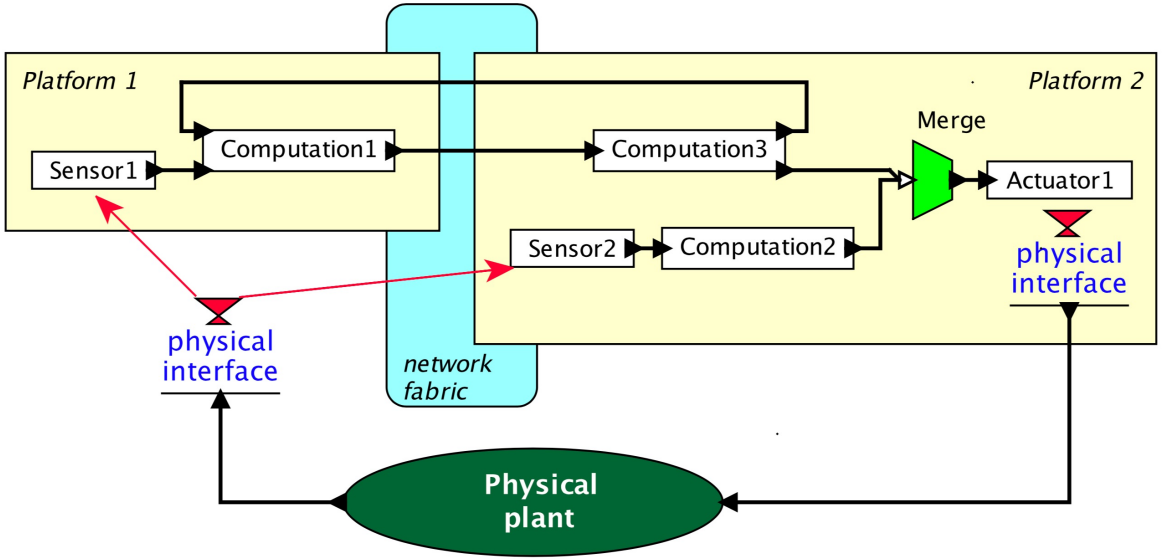


Hype Cycle 2018



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

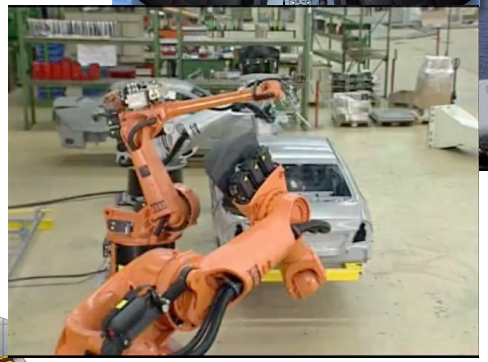
- Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the *seamless integration* of computation and physical components.
- Advances in CPS will *enable* capability, adaptability, scalability, resiliency, safety, security, and usability that will expand the horizons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

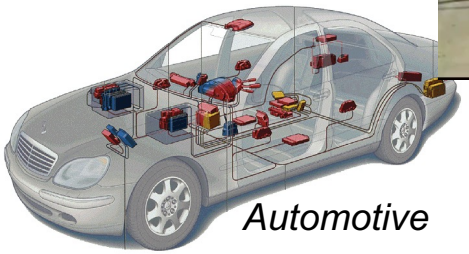
- Agriculture, Aeronautics, Building design, Civil infrastructure, energy, environmental quality, healthcare and personalized medicine, Manufacturing, and transportation.

CPS

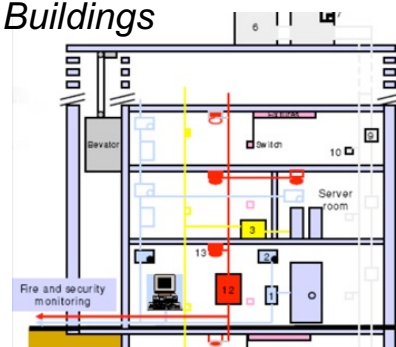
- Cyber + Physical
- Computation + Dynamics + Communication
- Security + Safety



Manufacturing



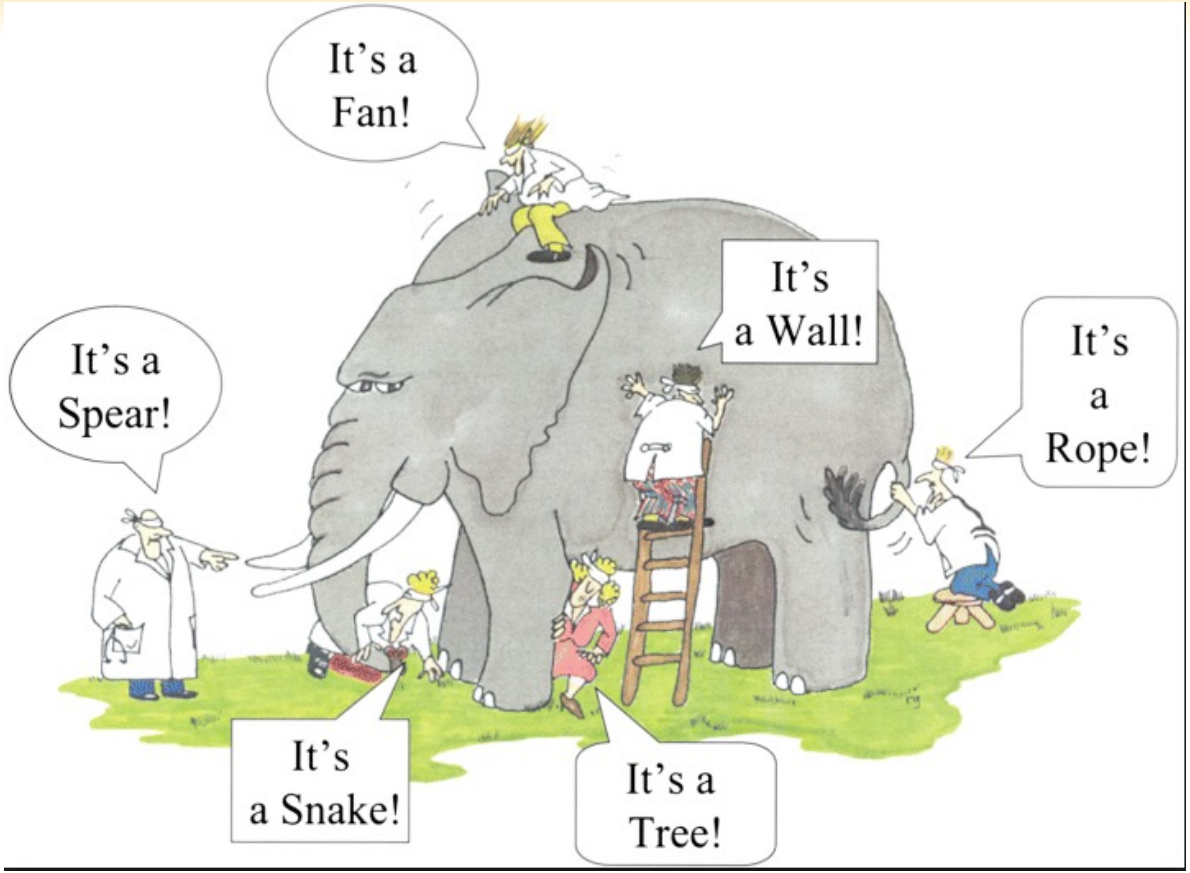
Automotive



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



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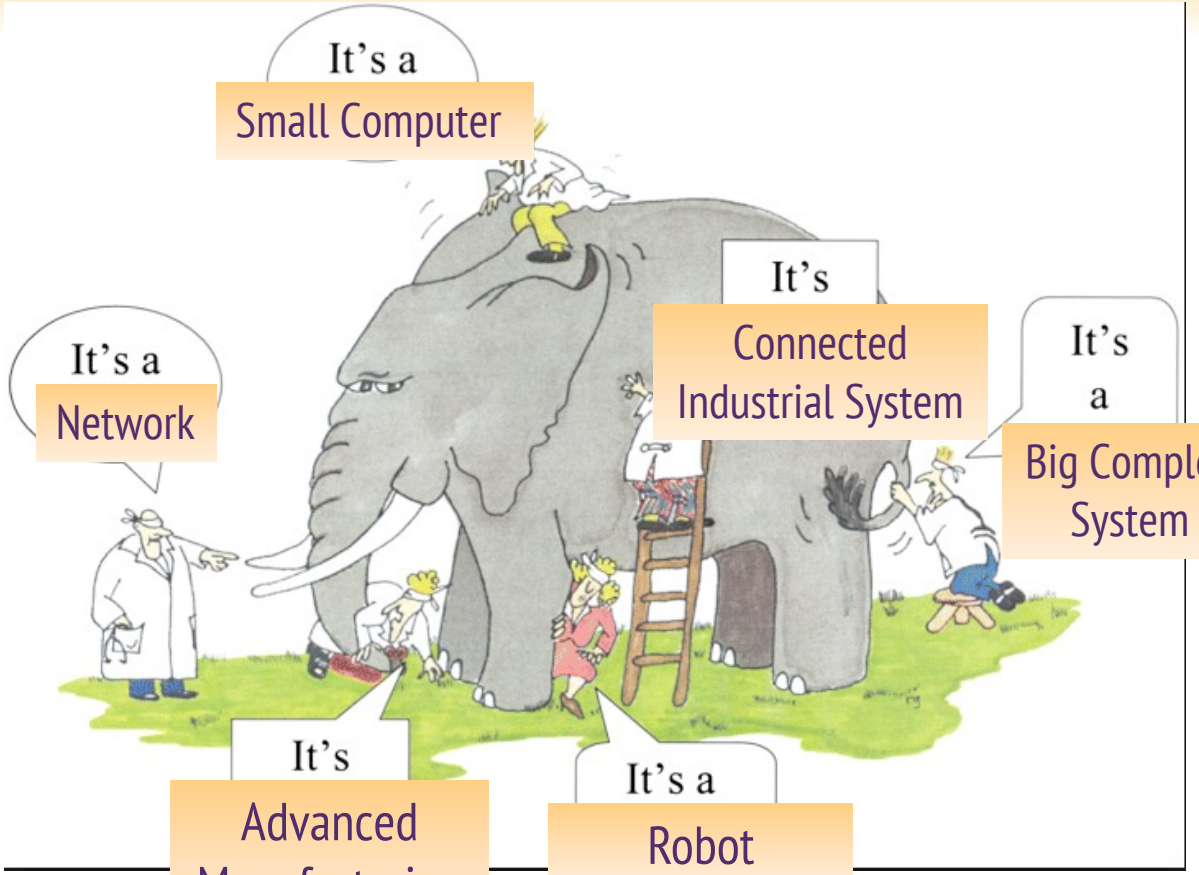
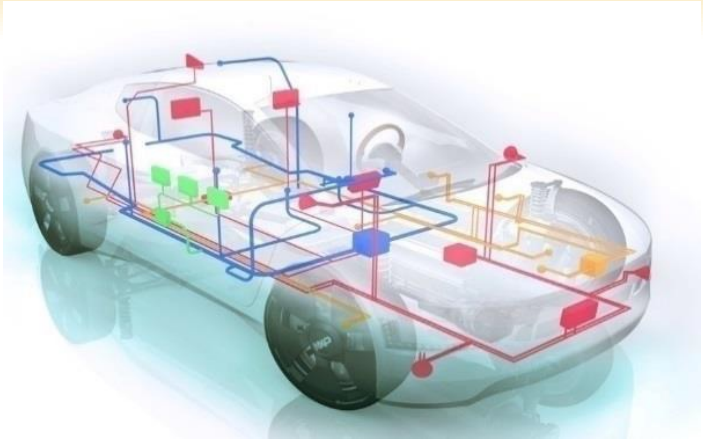
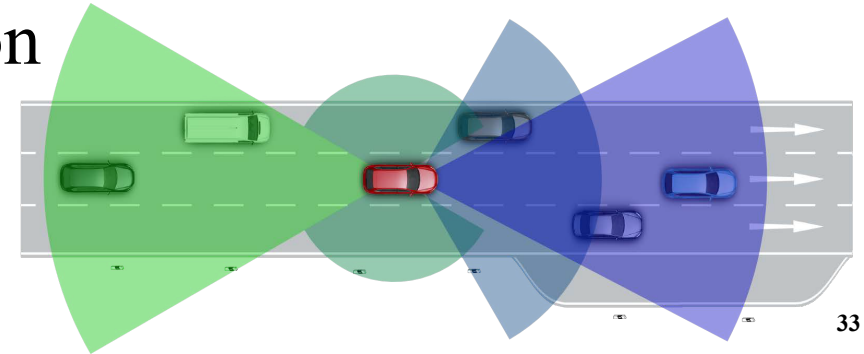


Automotive CPS

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

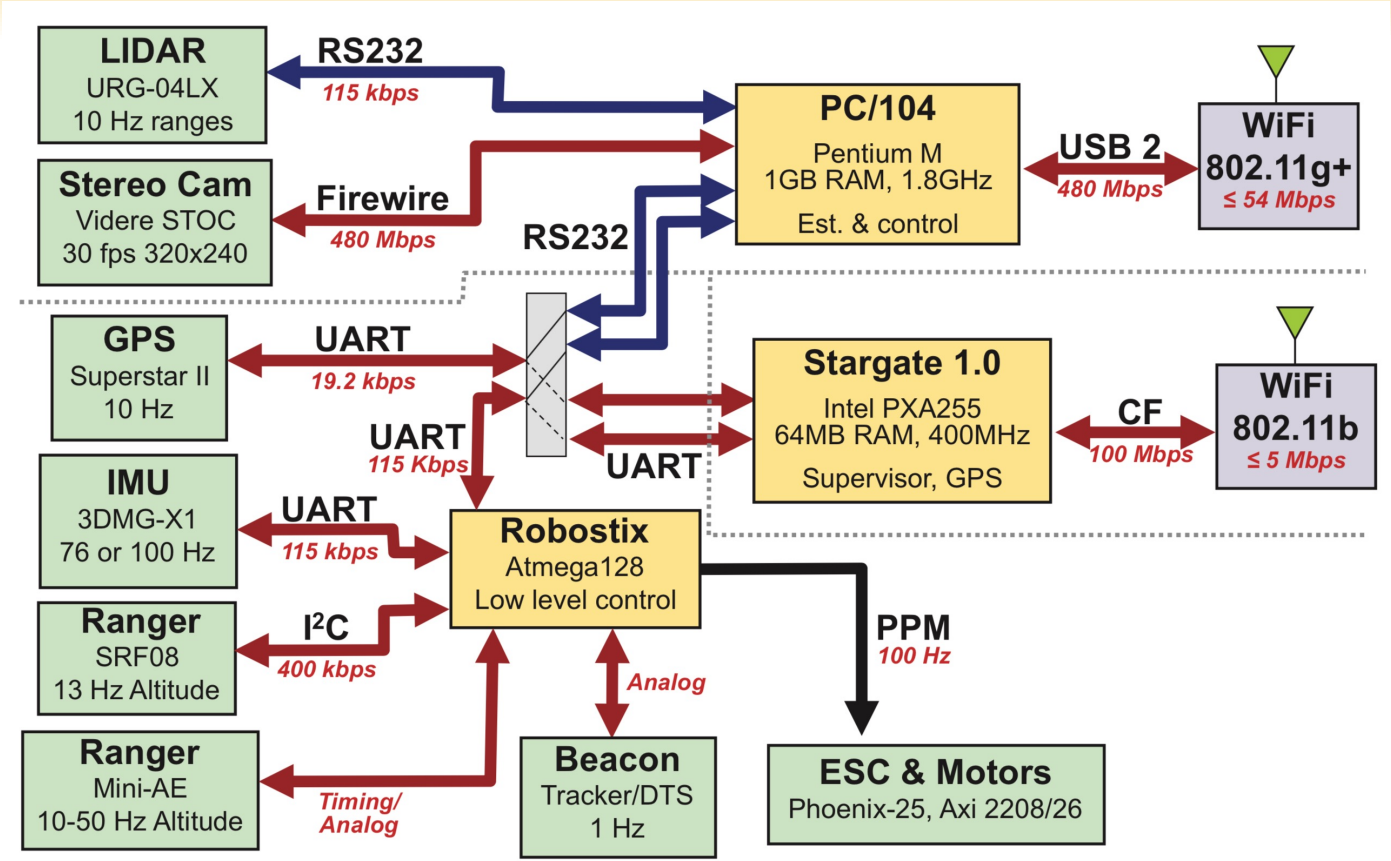




Example CPS System

- STARMAC Quadrotor Aircraft

STARMAC Design Block



What is this course about?

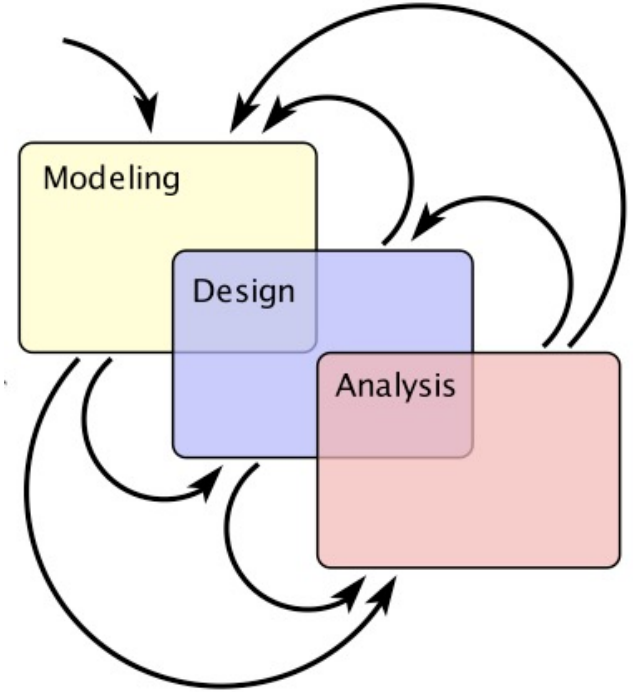
- A scientific structured approach to designing and implementing embedded systems
- Not just hacking and implementing
- Focus on model-based system design, on embedded hardware and software

Model, Design & Analysis

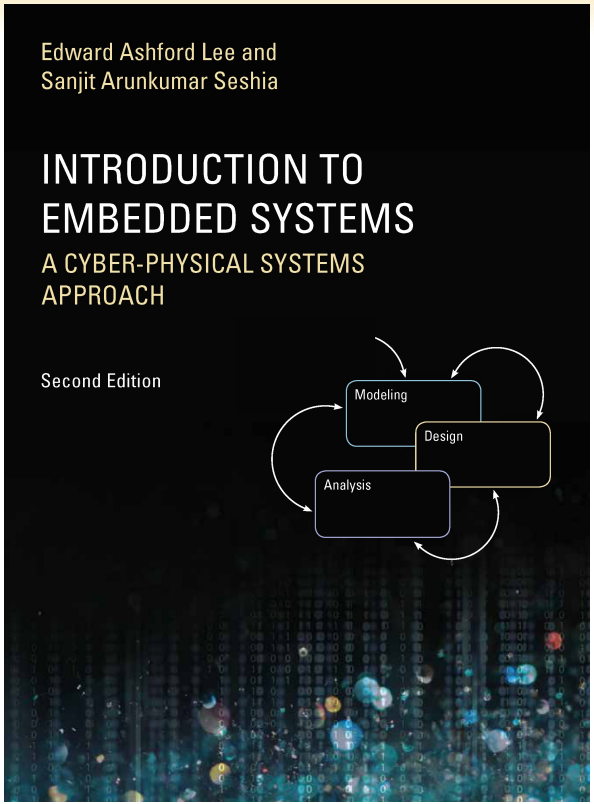
- ***Modeling*** is the process of gaining a deeper understanding of a system through imitation. Models specify **what** a system does.

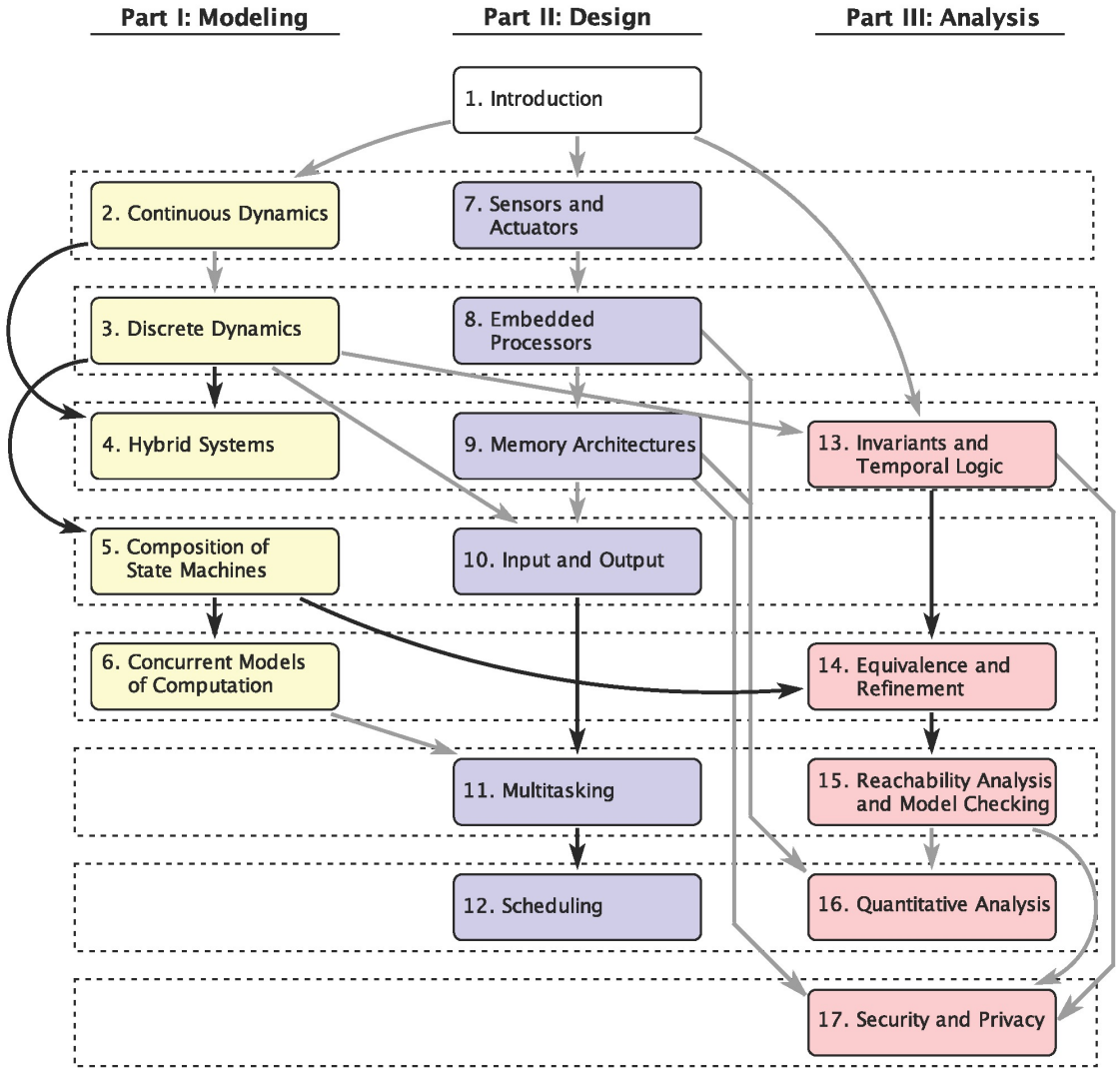
- ***Design*** is the structured creation of artifacts. It specifies **how** a system does what it does. This includes optimization.

- ***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