Cyber-Physical Systems

Introduction

UNIVERSITY AT ALBANY
State University of New York

IECE 553/453, ICSI 553 – Fall 2022

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
  - Aritra Dey
  - adey2@albany.edu
- Students (Identify your course and areas of interest)
  - Communications & Networking, Signal & Information Processing, Computer Engineering, Electronic Circuits & Systems

Students

Information

- Course Website:
  - https://www.albany.edu/faculty/dsaha/teach/2022Fall_ECE553/2022Fall_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
Location – ETEC 213
Monday – 1:00-2:00pm
Wednesday – 12:00-1:00pm

Pre-Requisite

- Programming at the Hardware Software Interface
- Signals & Systems
- The students are expected to be comfortable in
  - Unix/Linux environment
  - Basic Circuits

Textbooks *Slides in this course will be taken from these books.*

- 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.
  - William Shots, "The Linux Command Line", available for download
  - LaTeX Tutorial in Overleaf - Link.
- 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

Assignments & Grading

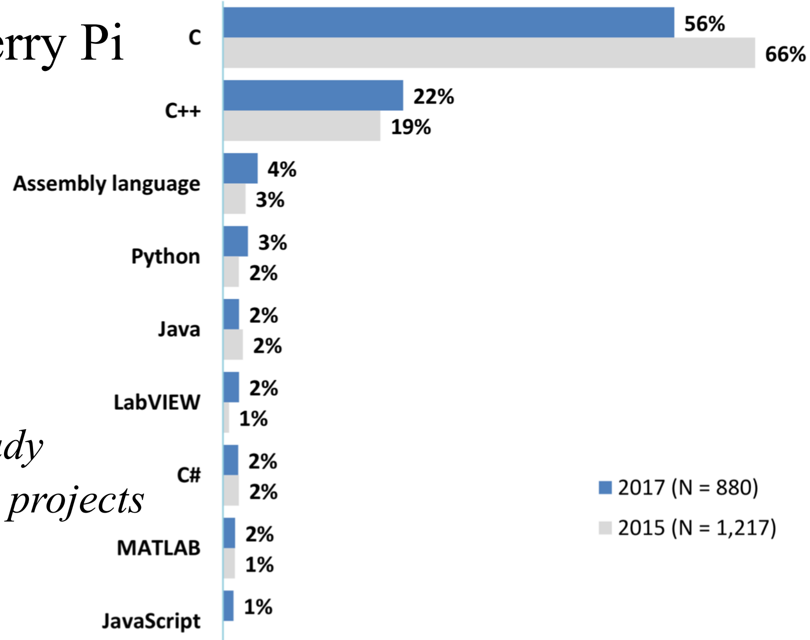
- Assignments
  - No late assignments will be accepted.
  - All assignments are due by 11:59PM on the due date in Blackboard.
  - Re-grading requests will be considered for up to 5 business days after posting the grades for the corresponding assignment.
- Grading
  - Labs (Pre and post-completion) - 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
- Midterm – Written, closed book
- Final – Written, closed book
  - **Dec 12: 1:00PM-3:00PM**
- Project (details in later slides)

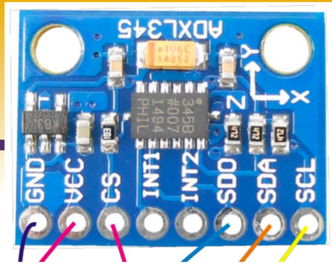
Lab

- Hardware:
  - Loan Raspberry Pi Kit from the Department
  - Purchase Sensor Kit (Adeept or Amazon)
  - Use Lab Manual to setup Headless Raspberry Pi
- Software:
  - Python, C/C++, Linux commands
  - LaTeX
  - Raspberry Pi OS

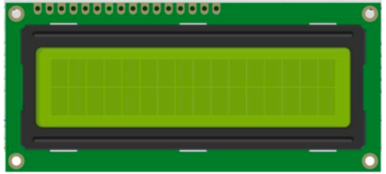


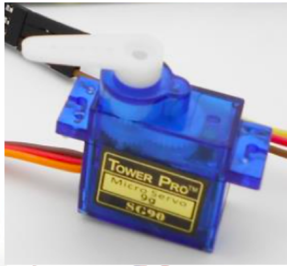
2017 Embedded Markets Study
Language used in embedded projects
eetimes

Sensor Kit – List of Items



- Triaxial Accelerometer Sensor Module
- DHT-11(Digital Temperature & Humidity Sensor)
- Ultrasonic Distance Sensor Module
- PIR Movement Sensor
- PS2 Joystick Module
- LCD1602
- Servo
- Stepper Motor
- Stepper Motor Driver Module (Based on ULN2003A)



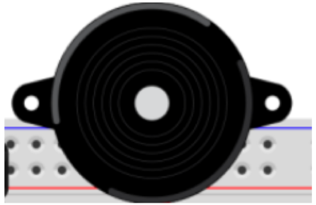


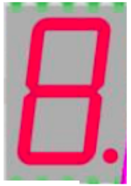
Sensor Kit – List of Items

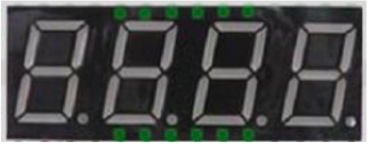
- ADC0832
- L9110 motor driver
- DC Motor
- 4*4 Matrix Keyboard
- Breadboard Power Supply Module
- 40 pin GPIO Extension Board
- 40 pin GPIO Cable
- Light Sensor (Photoresistor)
- Analog Temperature Sensor (Thermistor)

Sensor Kit – List of Items

- Relay
- Active Buzzer
- Passive Buzzer
- 7-Segment Display
- 4-bit 7-segment Display
- LED Bar Graph Display
- Dot-matrix Display
- 74HC595 (Serial to parallel)
- Switches, LEDs, Buttons, Resistors, Capacitors







Sensor Kit - Lessons

- Lesson 1 Blinking LED
- Lesson 2 Active Buzzer
- Lesson 3 Passive Buzzer
- Lesson 4 Controlling an LED with a button
- Lesson 5 Relay
- Lesson 6 LED Flowing Lights
- Lesson 7 Breathing LED
- Lesson 8 Controlling a RGB LED with PWM
- Lesson 9 7-segment display

Sensor Kit - Lessons

- Lesson 10 4-digit 7-segment display
- Lesson 11 LCD1602
- Lesson 12 A Simple Voltmeter
- Lesson 13 Matrix Keyboard
- Lesson 14 Measure the distance
- Lesson 15 Temperature & Humidity Sensor—DHT-11
- Lesson 16 Dot-matrix display
- Lesson 17 Photoresistor

Sensor Kit - Lessons

- Lesson 18 Thermistor
- Lesson 19 LED Bar Graph
- Lesson 20 Controlling an LED through LAN
- Lesson 21 Movement Detection Based on PIR
- Lesson 22 DC Motor
- Lesson 23 How to control a servo
- Lesson 24 How to control a stepper motor
- Lesson 25 Acceleration sensor ADXL345
- Lesson 26 PS2 Joystick

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

- Choose a 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

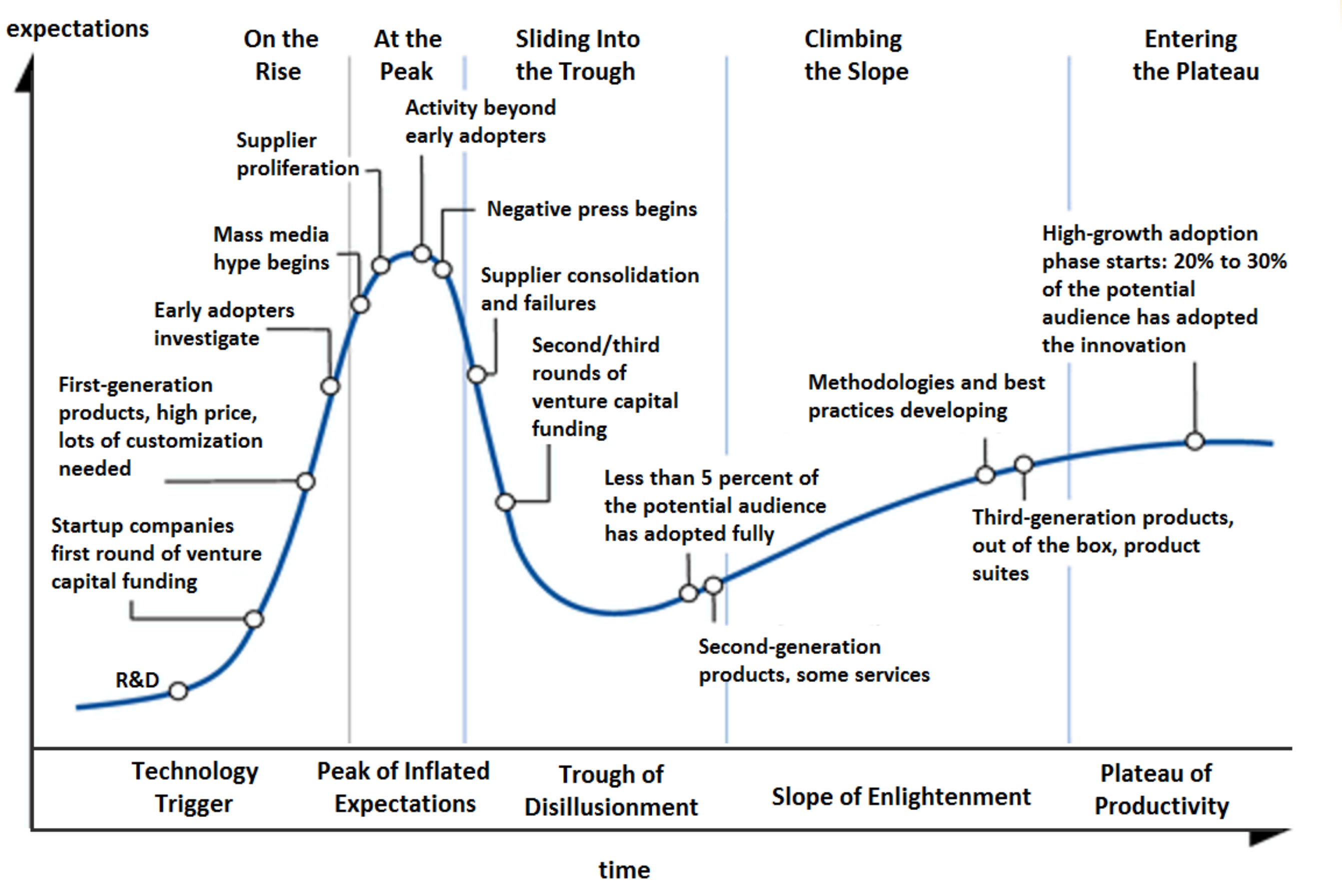
In Class Decorum

- 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

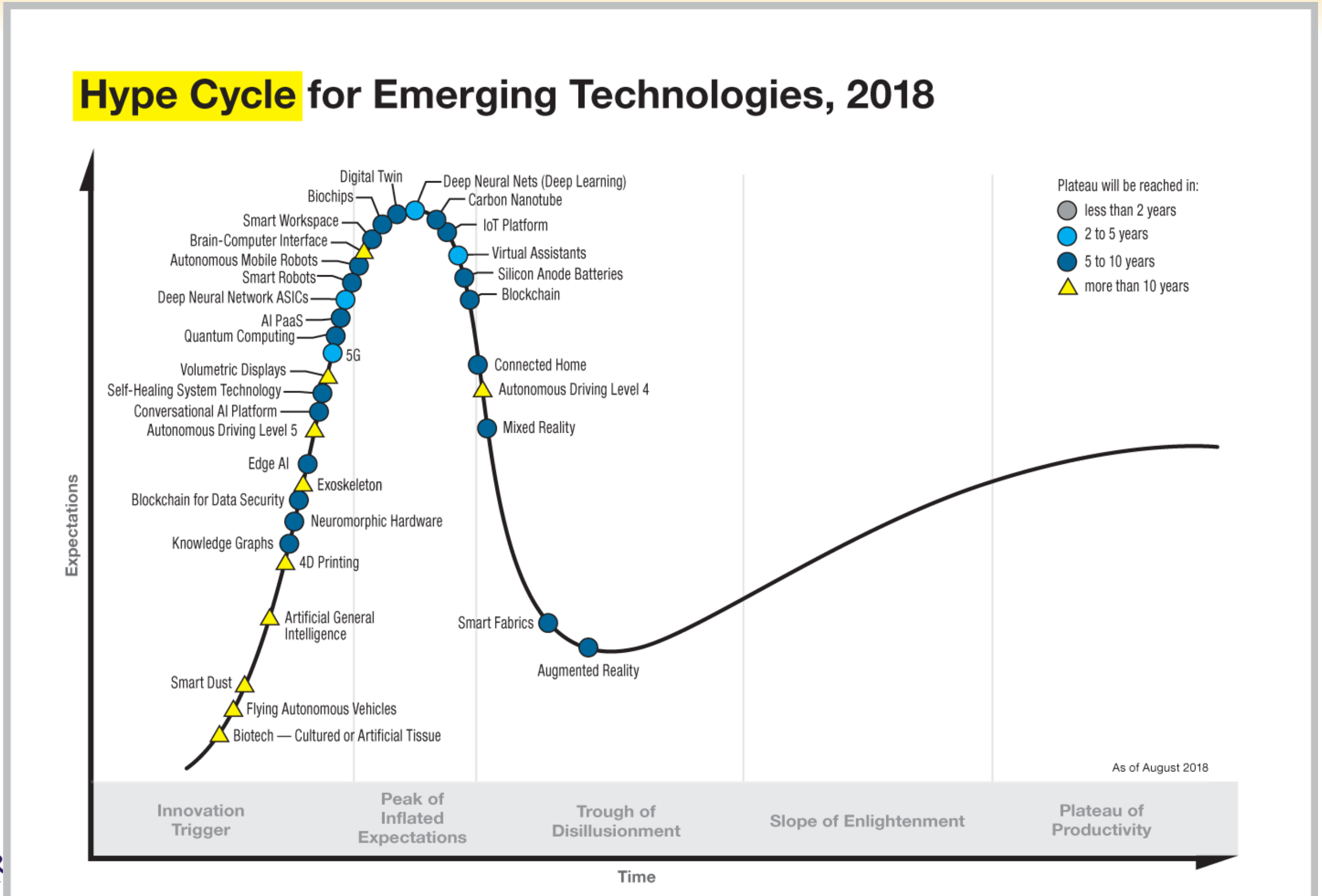
Why this course?

Hype Cycle

- gartner.com

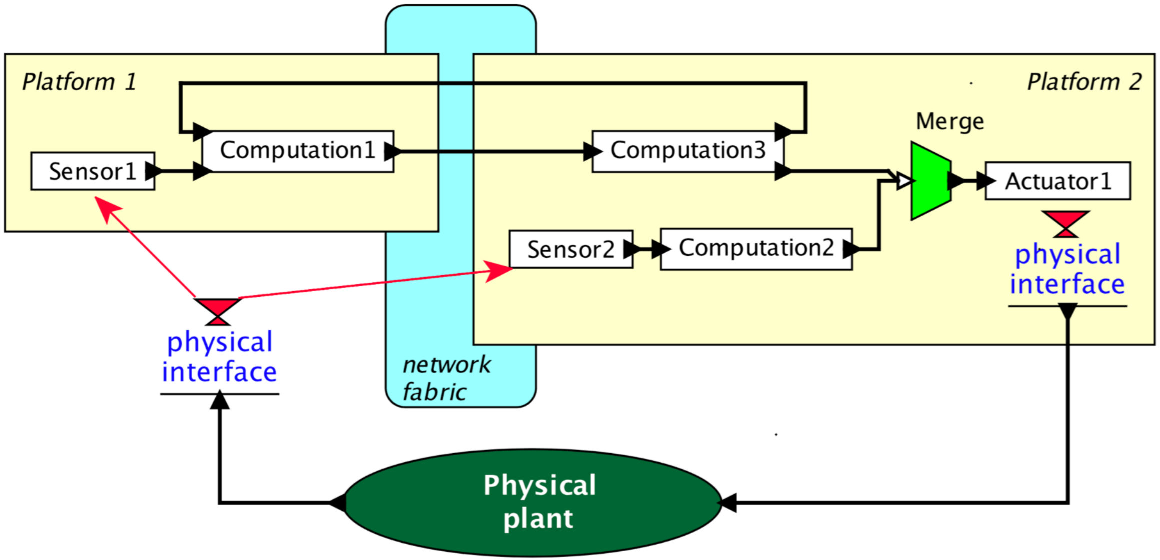


Hype Cycle 2018



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

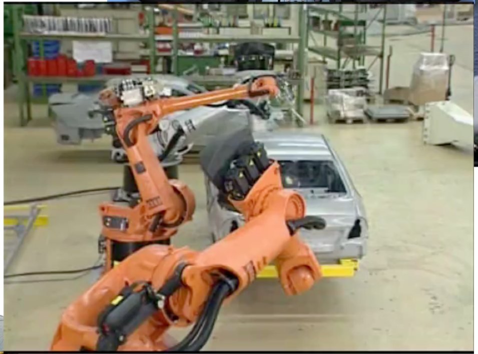
- Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the *seamless integration* of computation and physical components.
- Advances in CPS will *enable* capability, adaptability, scalability, resiliency, safety, security, and usability that will expand the horizons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

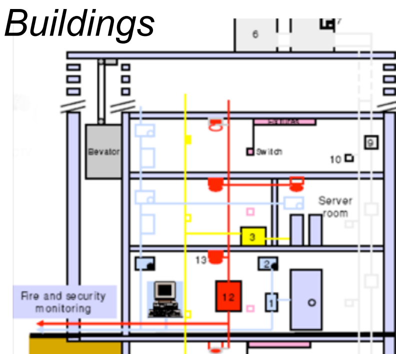
- Agriculture, Aeronautics, Building design, Civil infrastructure, energy, environmental quality, healthcare and personalized medicine, Manufacturing, and transportation.

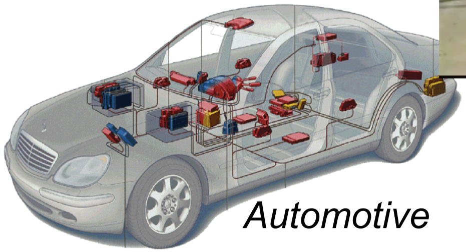
CPS

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



Manufacturing



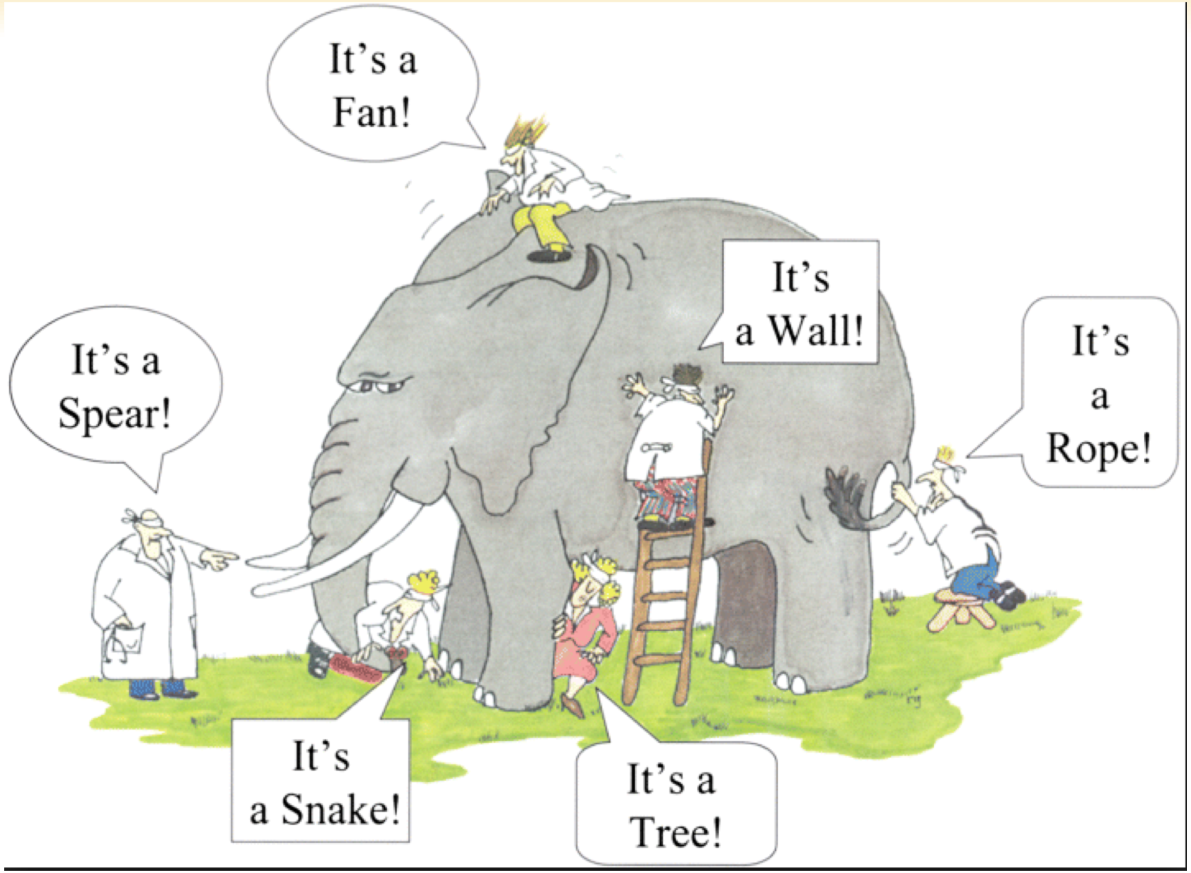


Automotive

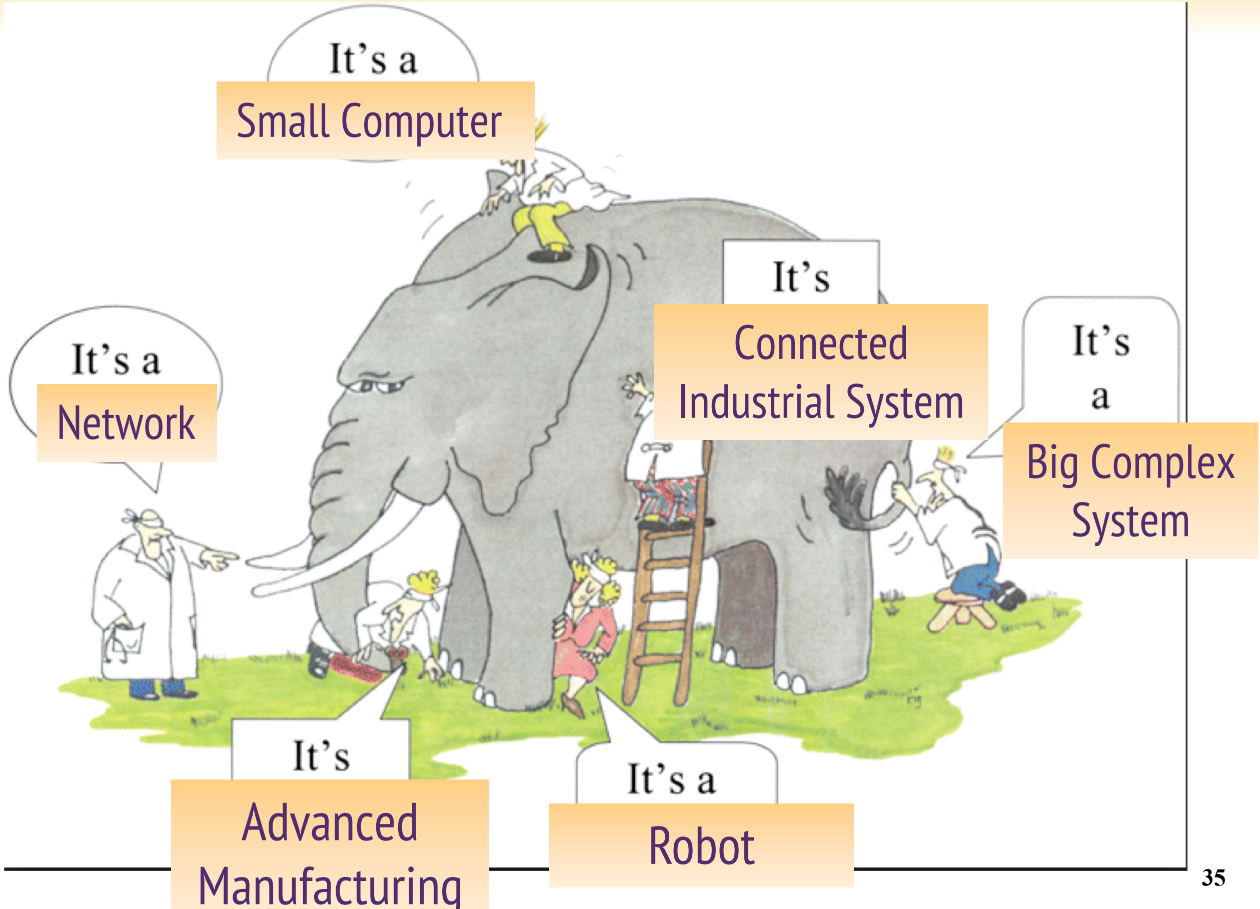
Contradictions in CPS

- 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

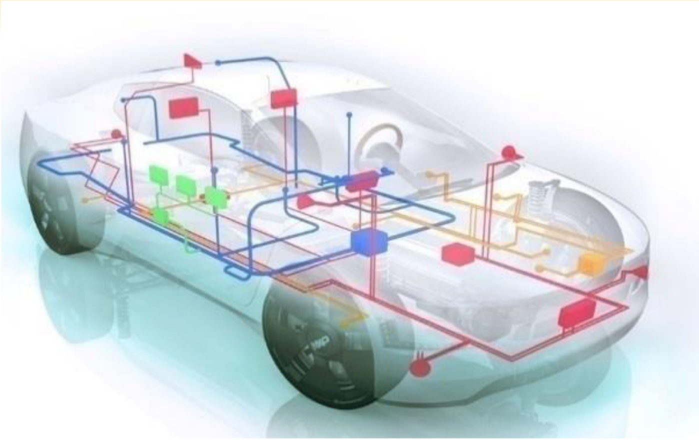


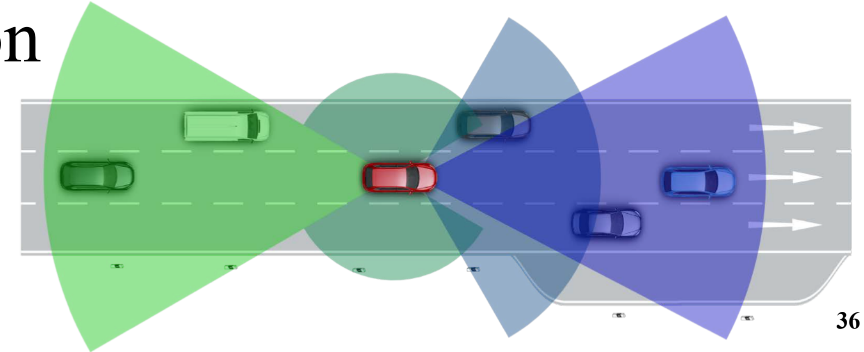
Challenges of Working in a Multidisciplinary Area



Automotive CPS

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

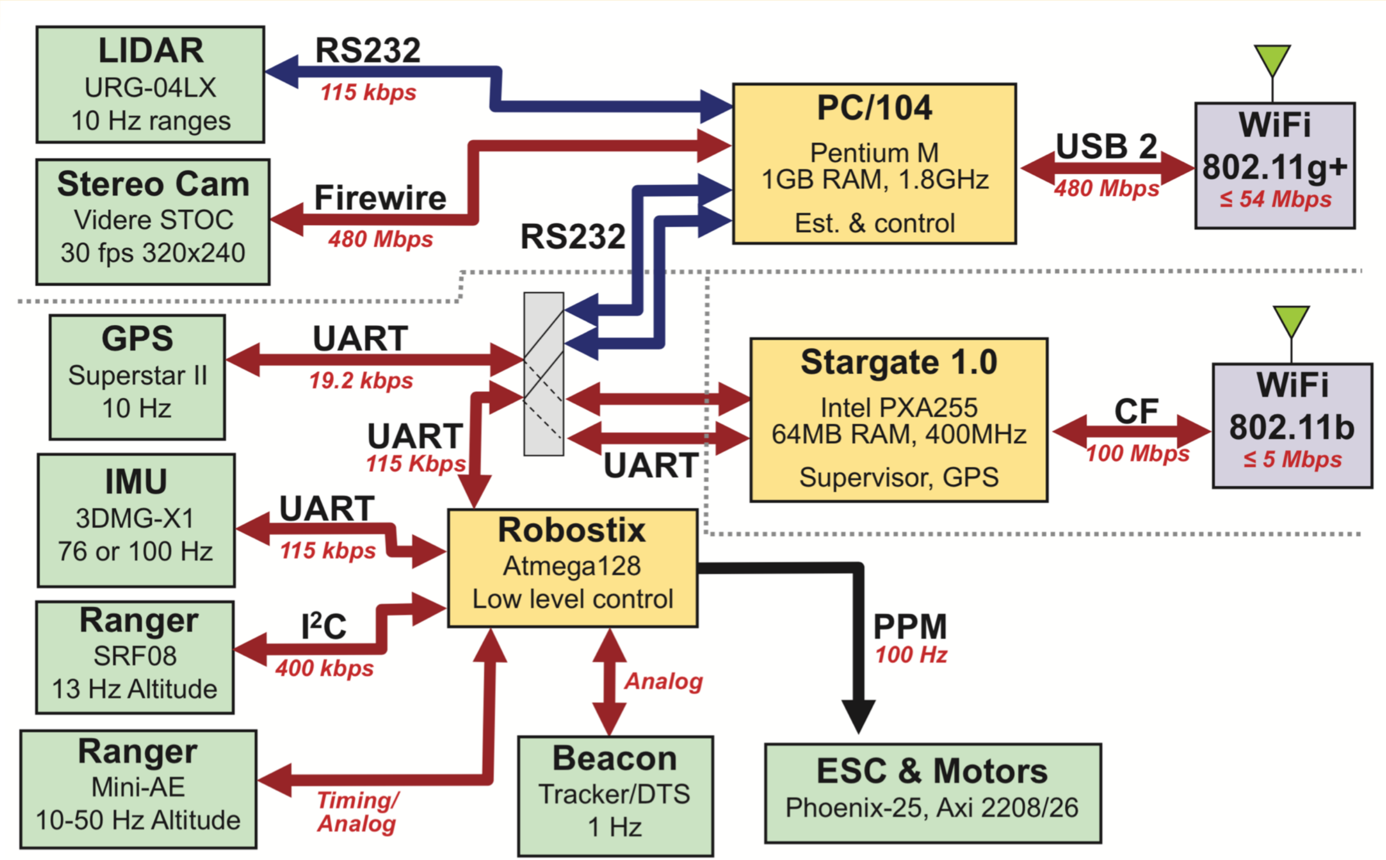




Example CPS System

- STARMAC Quadrotor Aircraft

STARMAC Design Block



What is this course about?

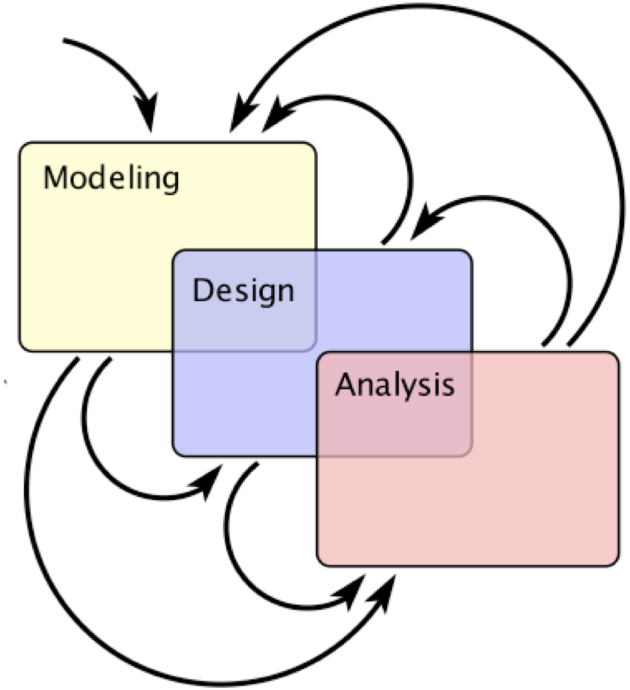
- A scientific structured approach to designing and implementing embedded systems
- Not just hacking and implementing
- Focus on model-based system design, on embedded hardware and software

Model, Design & Analysis

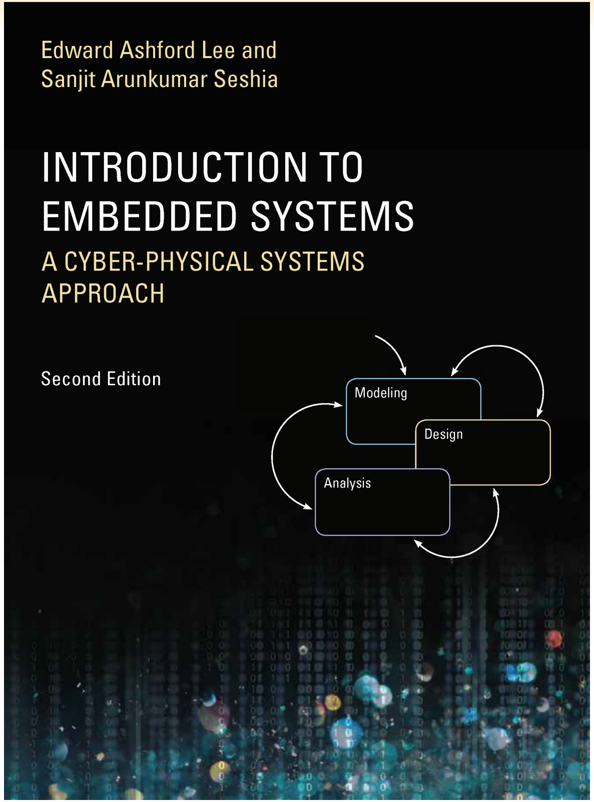
- ***Modeling*** is the process of gaining a deeper understanding of a system through imitation. Models specify **what** a system does.

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

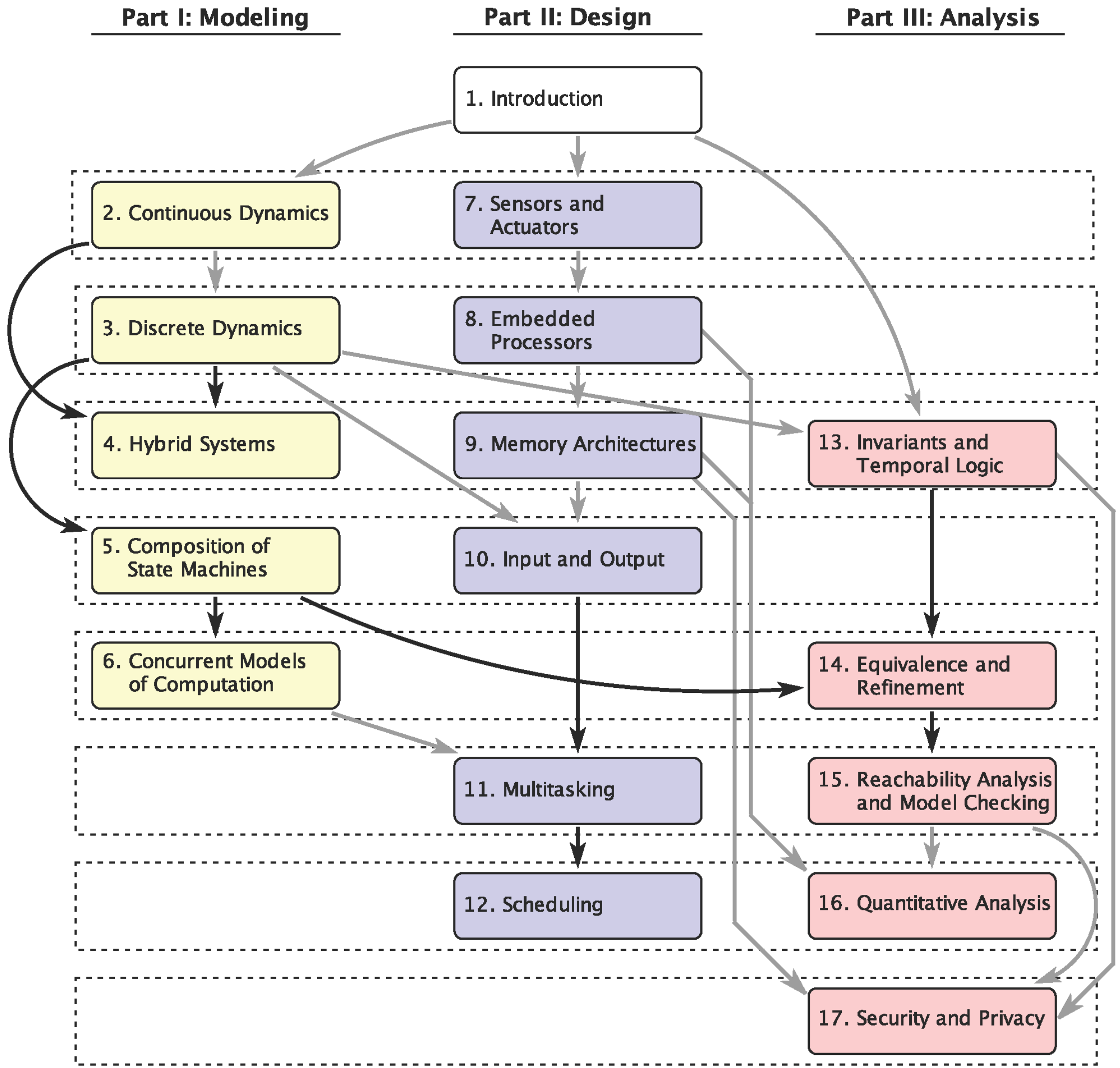
- ***Analysis*** is the process of gaining a deeper understanding of a system through dissection. It specifies **why** a system does what it does (or fails to do what a model says it should do).



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