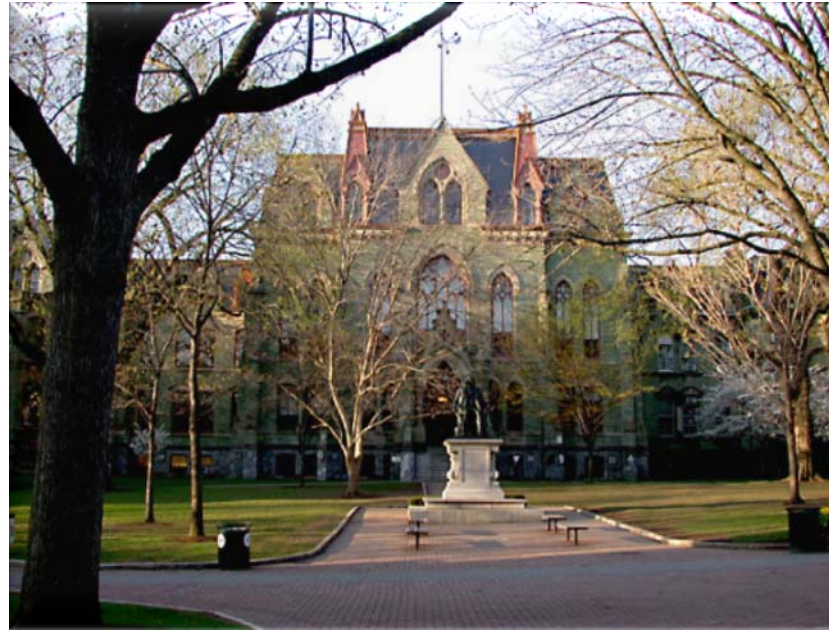


# Cyber-physical systems Educational Challenges



George J. Pappas

Department of Electrical and Systems Engineering

University of Pennsylvania

[pappasg@seas.upenn.edu](mailto:pappasg@seas.upenn.edu)



# Main educational objective

**Objective:** Convey a unified view of communication, control, and computing

**Approach 1:** Everyone is an expert in everything  
Challenge: Scalability

**Approach 2:** A systems view of everything  
Challenge: Emphasize similarities and differences

# Modeling, reconsidered

In computing, automaton is the key abstraction

In the physical world, o.d.e. is the key abstraction

Given these robust models, emphasis was on analysis

For cyber-physical systems, our abstractions are under development and constantly reconsidered

Curricula should be re-emphasize modeling, perhaps by delaying some analysis and design

# Systems View of Computing

- Transform computing education from a science of languages to a science of computing systems
  - Formal methods for all CS undergraduates?
- More emphasis on concurrency and distributed algorithms
- Emphasize uncertainty and physicality into computer models  
Timing, physical, environment, failures, etc
- From exact to approximate thinking  
Probabilistic reasoning

# Control and Sensing

- Much more emphasis on system composition
  - Too much emphasis on feedback design over transfer functions
- Heterogeneous system composition
  - Many notions of time
  - Synchronous, asynchronous, distributed etc
- Emphasize time-domain over frequency-domain
- Digital control systems should re-emphasize embedded control and sensing over modern computing platforms
  - Digital control courses are obsolete

# Mathematical challenges

- Much has been said about the discrete and continuous math discrepancies
- Calculus I, II, III, IV sequences were designed in the 19<sup>th</sup> century and it is time to rethink them
- Linear algebra in freshman year
- Probability for everyone

# Curriculum challenges

- It is conceivable to develop an undergraduate major on cyber-physical systems
- It is probably impossible to institutionalize it within any university
- But it may be a lot easier to achieve this across universities with open access educational materials