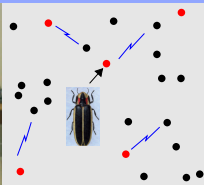


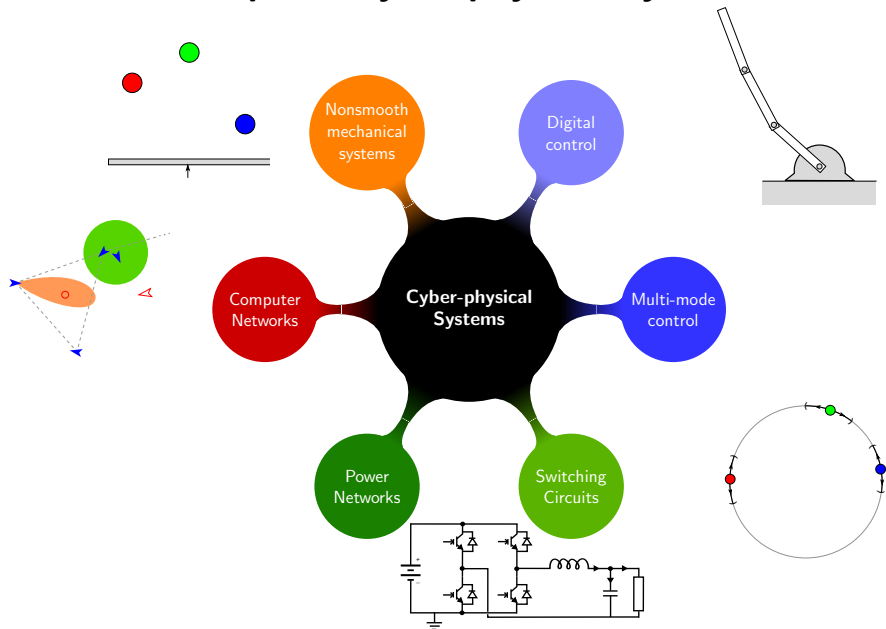
CMPE 142: Introduction to Cyber-physical Systems (CPS)

Ricardo Sanfelice

Department of Computer Engineering
Hybrid Dynamics and Control Lab
University of California, Santa Cruz



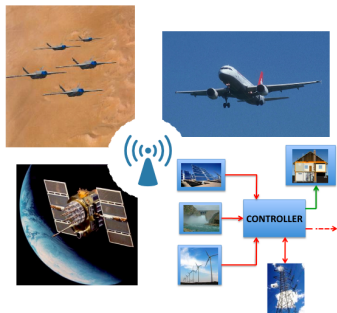
Broad Scope of Cyber-physical Systems



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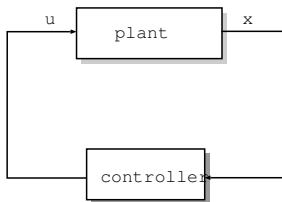
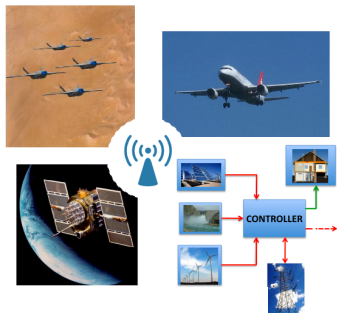
- ▶ Heterogeneous components and interfaces
(e.g. humans, networks, analog/digital devices).
- ▶ Modular hardware for flexibility and reconfigurability.
- ▶ Distributed coordination and control.



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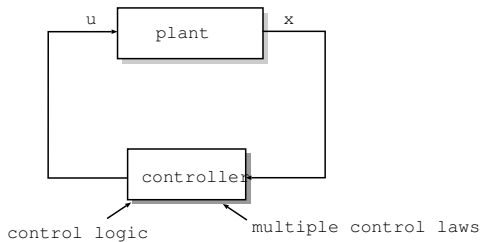
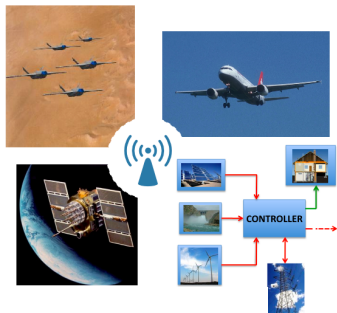
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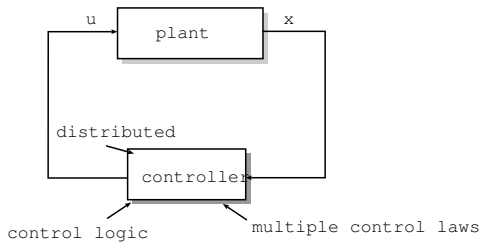
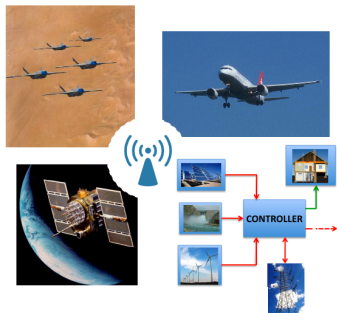
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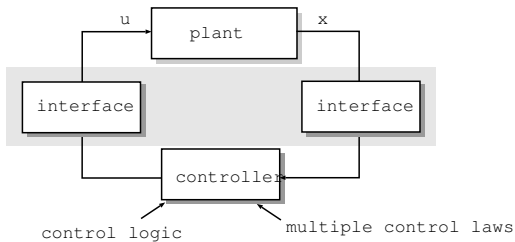
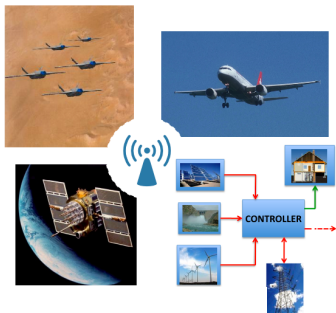
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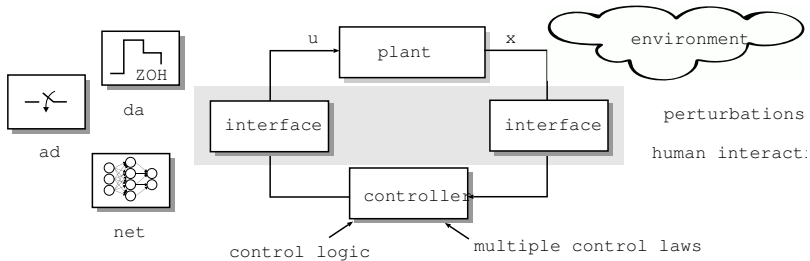
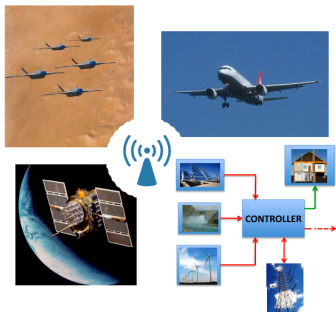
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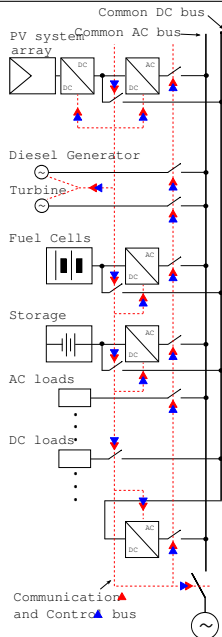
Sample CPS Projects

Feedback Control for Smart Grids

- ▶ Heterogeneous networked power sources, buses, users, and loads
- ▶ Conversion required between different waveforms
- ▶ Dynamic demands and supplies
- ▶ Multiple time scales
(e.g., fast and slow switching)

Classical approaches:

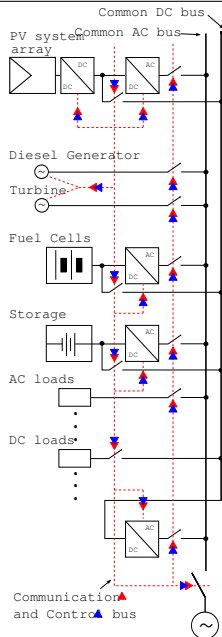
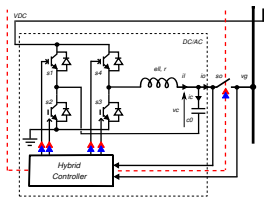
- ▶ Steady-state and averaged models
- ▶ Linear control design
- ▶ Bening conditions



Sample CPS Projects

Power Conversion for Smart Grids

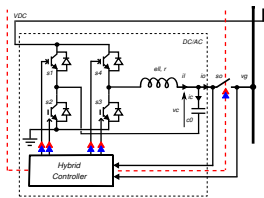
- ▶ Renewables provide power with high fluctuation
- ▶ DC/DC conversion is required before injection to the grid
- ▶ Adaptive DC/AC conversion



Sample CPS Projects

Power Conversion for Smart Grids

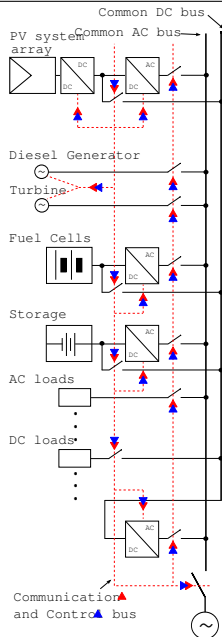
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High Penetration of Renewables

U.S.: 20% by 2030

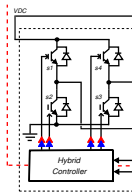
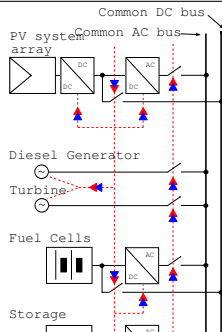
Europe: 16% by 2020



Sample CPS Projects

Power Conversion for Smart Grids

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Collaboration with Sandia National Labs on testing of control algorithms in their platform (DETL)



High Penetration of Renewables

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Sample CPS Projects

Control of Reconfigurable Multi-Robot Systems

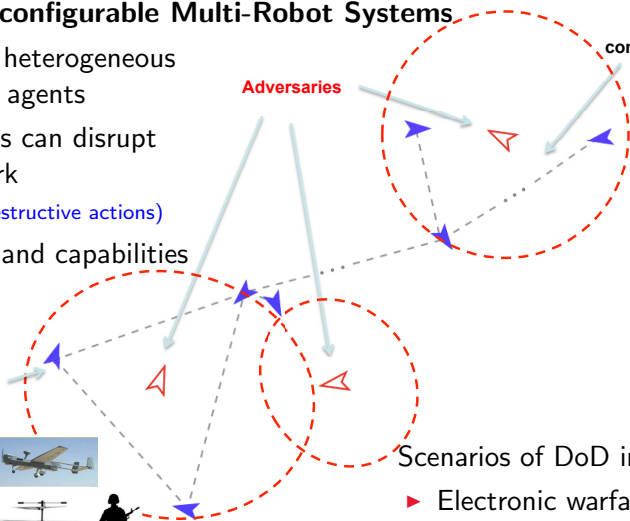
- ▶ Groups of heterogeneous networked agents
- ▶ Adversaries can disrupt the network
(jamming, destructive actions)
- ▶ Locations and capabilities unknown

Static and Mobile Agents



Adversaries

dynamic communication network



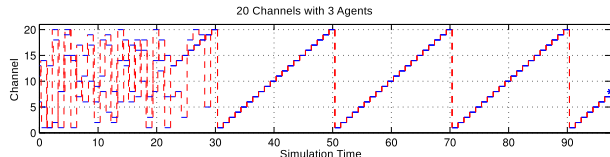
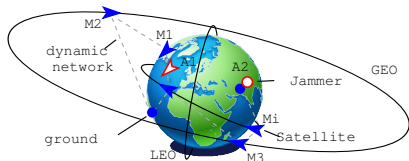
Scenarios of DoD interest:

- ▶ Electronic warfare
- ▶ Satellite communications
- ▶ Disaster relief

Sample CPS Projects

Reconfigurable Satellite Communications

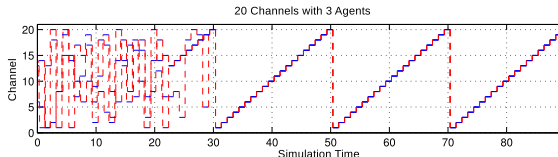
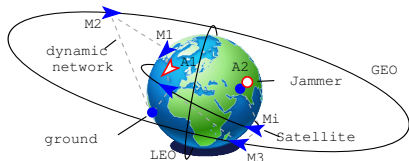
- ▶ Dynamic ground-satellite links
- ▶ Dynamic signal-to-noise ratio on communication channels
- ▶ Jamming attacks (MILSATCOM)



Sample CPS Projects

Reconfigurable Satellite Communications

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Recent initiatives, such as the **National Broadband Plan**, challenge the traditional FCC approach to allocating spectrum, requesting a new U.S. spectrum policy allowing for dynamic allocation and utilization.

Sample CPS Projects

Control of Aerial Vehicles with Limited and Faulty Sensors

- ▶ Autonomous recovery control
- ▶ Low cost sensing for autonomous navigation
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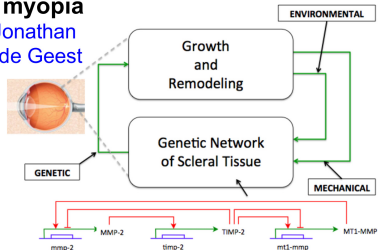
- ▶ Autonomous recovery control
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UAVs in the National Air Space (NAS): 2012 bill giving FAA three years to “integrate” UAVs into the NAS ([set policies, standards, etc.](#))

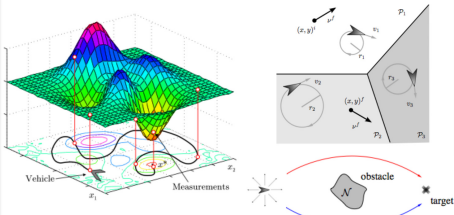
Sample CPS Projects

Genetic + growth/remodeling models for myopia

w/ Jonathan vande Geest

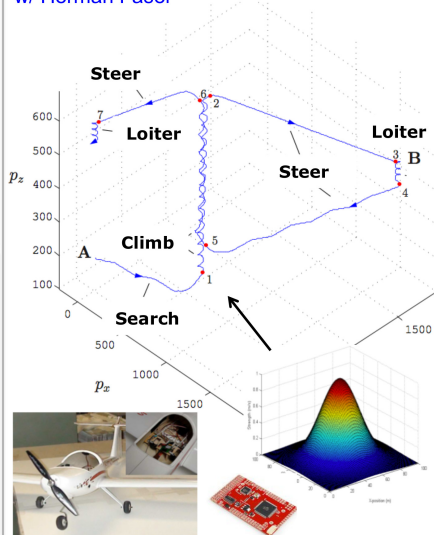


Control of UGVs in cluttered and heterogeneous environments



Autonomous soaring

w/ Herman Fasel



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- ▶ Understand core theoretical concepts needed to study CPS
- ▶ Apply tools and concepts to a CPS application

Course Description

*Cyber-physical systems combine digital and analog devices, interfaces, networks, computer systems, and the like with the natural and man-made physical world. The inherent interconnected and heterogeneous combination of behaviors in these systems makes their analysis and design a challenging task. Safety and reliability specifications imposed in cyber-physical applications, which are typically translated into stringent robustness standards, aggravate the matter. Unfortunately, state-of-the-art tools for system analysis and design cannot cope with the intrinsic complexity in cyber-physical systems. **Tools suitable for analysis and design of cyber-physical systems must allow a combination of physical or continuous dynamics and the cyber or computational components, as well as handle a variety of types of perturbations, such as exogenous disturbances, time delays, and system failures.***

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- ▶ Linear temporal logic
- ▶ Verification

Some Items in Fine Print

Prerequisites: The course is self contained. Students are expected to have basic background on logic circuits (CMPE 100 or equivalent), programming (CMPE 13 or equivalent), mathematical modeling of dynamical systems (CMPE 8 recommended), differential equations, linear algebra, and basic calculus. Knowledge of Matlab/Simulink will be useful.

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