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Hybrid Control Design

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Course Overview:

Hybrid dynamical systems, when broadly understood, encompass dynamical systems where states or dynamics can change continuously as well as instantaneously. Hybrid control systems arise when hybrid control algorithms — algorithms which involve logic, timers, clocks, and other digital devices — are applied to classical dynamical systems or systems that are themselves hybrid. Hybrid control may be used for improved performance and robustness properties compared to classical control, and hybrid dynamics may be unavoidable due to the interplay between digital and analog components of a system.

The course has two main parts. The first part presents various modeling approaches to hybrid dynamics, focuses on a particular framework which combines differential equations with difference equations (or inclusions), and present key analysis tools. The ideas are illustrated in several applications. The second part presents control design methods for such rich class of hybrid dynamical systems, such as supervisory control, CLF-based control, invariance-based control, and passivity. A particular goal of the course is to reveal the key steps in carrying over such methodologies to the hybrid dynamics setting. Each proposed module/lecture is designed to present key theoretical concepts as well as applications of hybrid control of current relevance..

Course Outline:

- **Part 1: Introduction, examples, and modeling.**
  - Theoretical topics: hybrid inclusions; solution concept, existence, and uniqueness.
  - Applications: hybrid automata, networked systems, and cyber-physical systems.

- **Part 2: Dynamical properties.**
  - Theoretical topics: continuous dependence of solutions, Lyapunov stability notion and sufficient conditions, invariance principles, and converse theorem.
  - Applications: synchronization of timers and state estimation over a network.

- **Part 3: Supervisory control, uniting control, throw-catch, and event-triggered control.**
  - Theoretical topics: logic-based switching, uniting control, throw-and-catch control, supervisory control, and event-triggered control.
  - Applications: aggressive control for aerial vehicles, control of the pendubot, obstacle avoidance, control of robotic manipulators.

- **Part 4: Synergistic control, CLF-based control, invariance-based control, and passivity-based control.**
  - Theoretical topics: synergistic control, control Lyapunov functions, stabilizability, Sontag-like universal formula for hybrid systems, selection theorems, invariance and invariance-based control, passivity-based control.
  - Applications: control for DC/DC conversion and for mechanical systems with impacts.

References available at https://hybrid.soe.ucsc.edu/biblio and upcoming book "Hybrid Feedback Control" to appear late 2018.