Control & Dynamic Systems Lab. @SNU

http://post.cdsl.kr

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- Ph.D @ SNU (2000)
- Assist. Professor @ Hanyang Univ. (2002 ~ 2003)
- Professor @ SNU (2003 ~ current)

We are working on "Control Theory"

- Develop control algorithms using mathematical tools
- Analyze dynamical behavior of complex systems
- Connect the gap between theory and industrial problems

"Nothing is more practical than a good theory." - Kurt Lewin

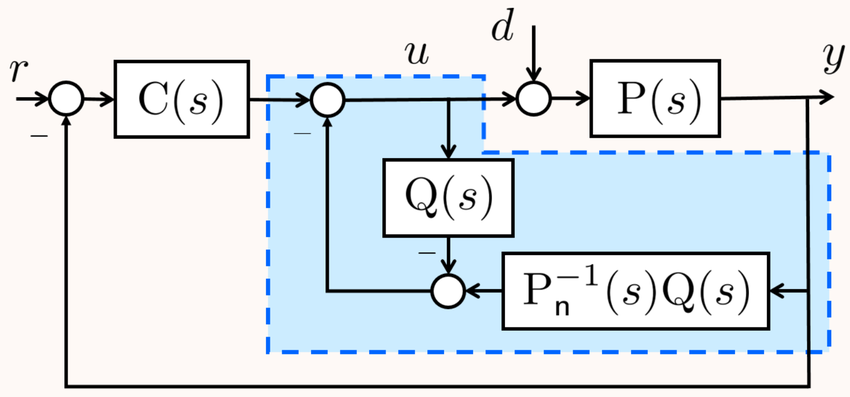
Mathematics

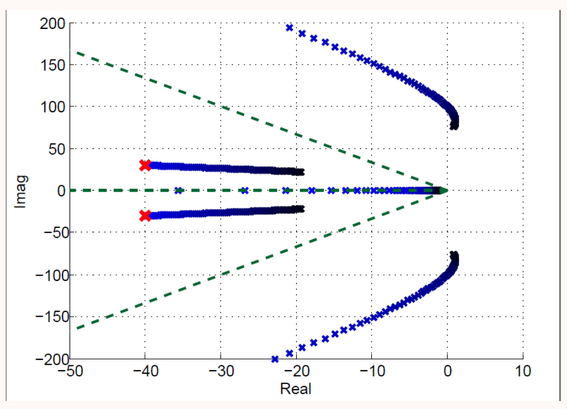
Control Theory

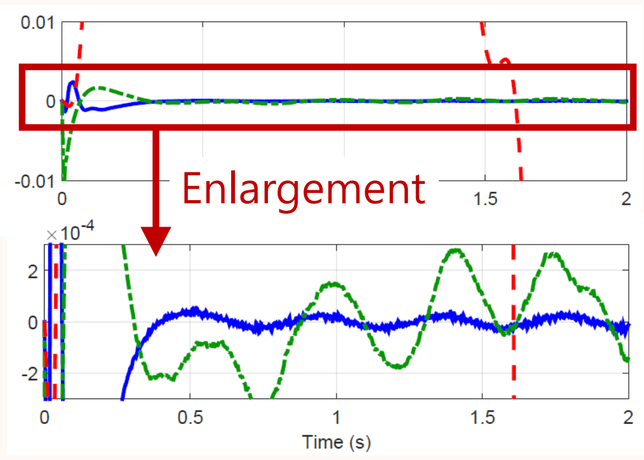
Engineering
(Electric, Mechanical,…)

Disturbance Observer

- A robust controller that compensates disturbance and uncertainty at once
- So far, successfully used in industry but with limited theoretical basis
- **CDSL's solution: "Analyze its behavioral tendency under large bandwidth of Q-filter"**
  - ✓ "Necessary and sufficient" condition for robust internal stability
  - ✓ Advanced design for nominal performance recovery (i.e., $y(t) \approx y_n(t), \forall t \geq 0$)
  - ✓ Extensions to nonlinear/MIMO/sampled-data systems, …



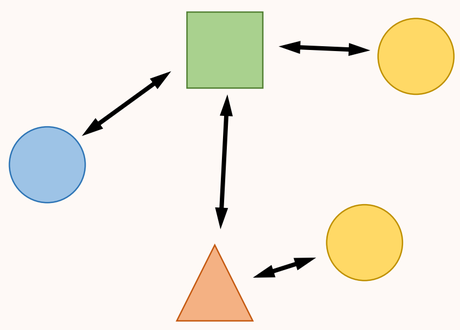




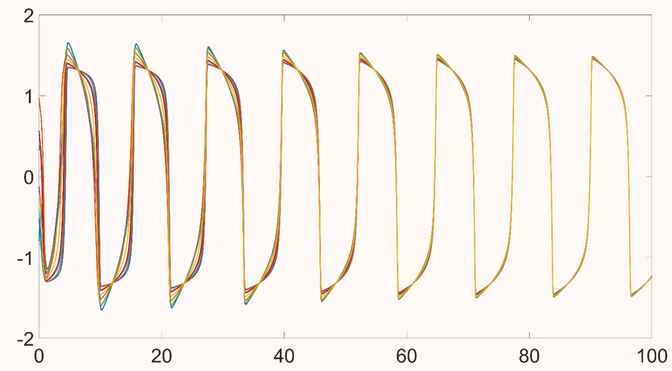
(a) Configuration (b) Root contour w.r.t. Q-filter bandwidth (c) $||y(t) - y_n(t)||$ w/ advanced design

Synchronization

- Study interactions of multiple agents to achieve a common goal in a distributed manner
- Most studies focused on homogeneous agents, which is limited in real world applications
- **CDSL's solution: "Diffusive coupling with high gain results in blended dynamics"**
  - ✓ All agents behave in similar manner, which is described by the blended dynamics
  - ✓ Applications of blended dynamics:
    - ① Distributed estimation problem in sensor network
    - ② Distributed optimization, e.g. economic dispatch problem in power network



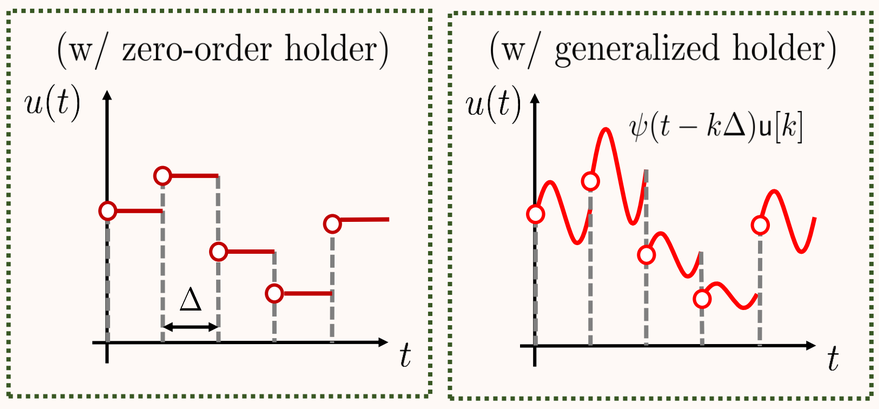
(a) Heterogeneous multi-agent system



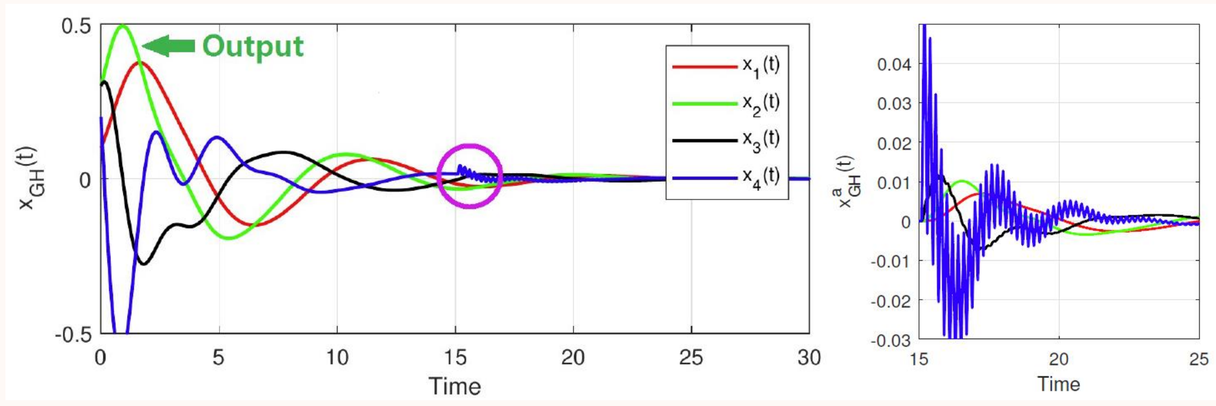
(b) Van Der Pol Oscillators with diffusive coupling

Security of Cyber-Physical Systems

- Modern control systems are exposed to critical cyber-attacks (e.g., STUXNET).
- Objective: Discover cyber-attack scenarios & develop its protection/detection methods
- **CDSL's solution:**
  "Address the security problems from systematic & control-theoretic perspective"
  - ✓ Sampling/robust zero-dynamics attacks: Stealthy attacks utilizing mathematical models
  - ✓ A countermeasure: Utilize generalize hold to modify plant's characteristics
  - ✓ Encrypt control systems using fully homomorphic authenticated encryption scheme



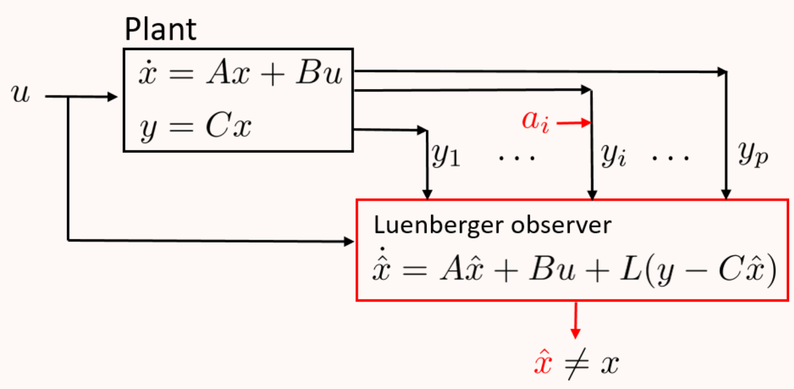
(a) Zero-order hold & generalized hold



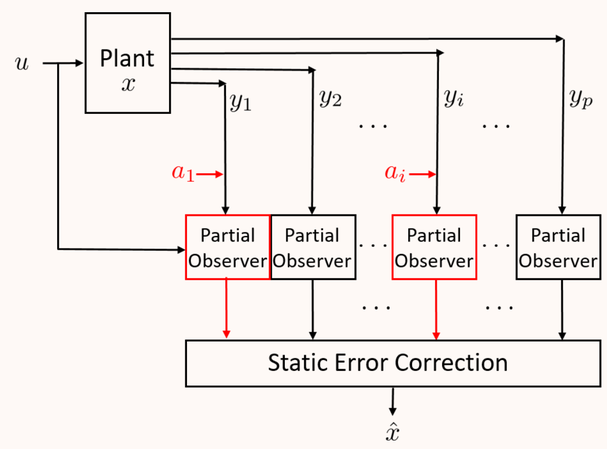
(b) Result of generalized hold under zero dynamics attack

Resilient State Estimation

- Objective: Identify sensor attack & estimate state only w/ trustworthy sensors
- Challenges w/ classical approaches: Computational complexity being NP-hard
- **CDSL's solution:**
  "Install observers for each output & collect and combine partial information of state"
  - ✓ Prevents the effect of attack from propagating to other estimates
  - ✓ Facilitates error correcting technique ⇒ reduces computational burden
  - ✓ Extension to uniformly observable systems & distributed attack identification



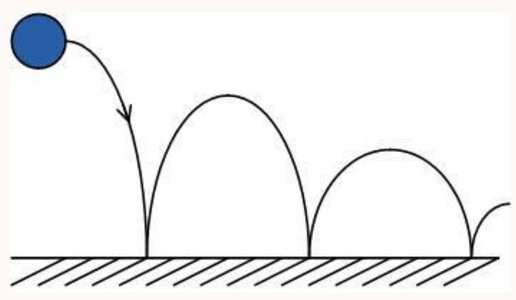
(a) Estimation failure in classical observer under sensor attack



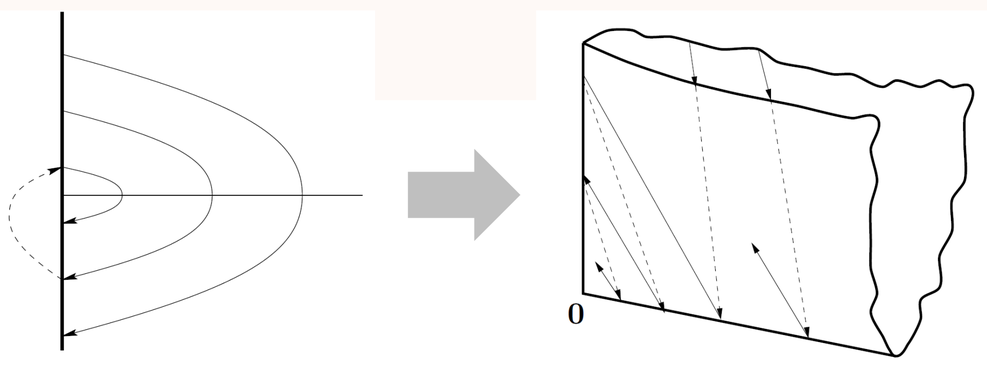
(b) Implementation of partial observers

State Estimation & Tracking Control of Hybrid System

- Hybrid systems: A dynamical system that exhibits both continuous and discrete behavior
- Its state estimation & tracking control: Not straightforward & requires complex algorithms
- **CDSL's solution: "Glue discontinuity of hybrid system using geometric control theory"**
  - ✓ Transforms a hybrid system into a continuous-time system without jump
  - ✓ Allows us to use widely-used techniques for continuous-time systems
    ⇒ Offers simplified designs of controller/observer for hybrid systems



(a) Bouncing ball



(b) Basic concept of gluing