CONTROL & DYNAMIC SYSTEMS

CDSL

LABORATORY

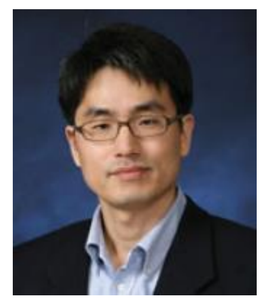
제어 및 동역학 연구실

Prof. Jin Heon Seo

Founder of Control & Dynamic Control Lab.

Ph.D at UCLA (1985)

Associate Professor at Texas Tech University



Prof. Hyungbo Shim

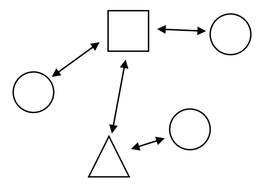
Director of Engineering Research Center for Advanced Control and Instrument

Ph.D at SNU (2000)

Research Topics

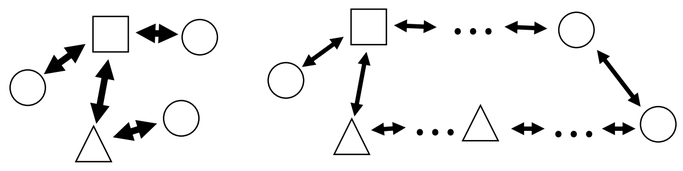
Consensus and Synchronization

- Multi-agent system connected via communication topology



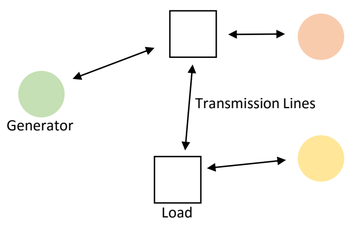
<Communication Graph>

- Design a **decentralized control** to achieve common objective across heterogeneous agents only using relative information



<Strong coupling & Large number of agents>

<Example>
Electrical Network



- Synchronize frequencies of various types of generator over transmission network

Security Problems of Control Systems

- Consider an actuator attack or a sensor attack model.

$$\dot{x}(t) = Ax(t) + B(u(t) + a_i(t))$$
$$y(t) = Cx(t) + a_s(t)$$

- Usual sensor attacks are detectable with anomaly detector

Estimator
$$\dot{\hat{x}}(t) = A\hat{x}(t) + Bu(t) + L(y(t) - \hat{y}(t))$$
$$\hat{y}(t) = C\hat{x}(t)$$

Residual
$$r(t) = y(t) - \hat{y}(t) = C(x(t) - \hat{x}(t)) + a_s(t)$$

Error dynamics
$$e := x - \hat{x} \quad \dot{e} = (A - LC)e + La_s$$
$$r = Ce + a_s$$

if $|r| \geq$ threshold, then alarm!

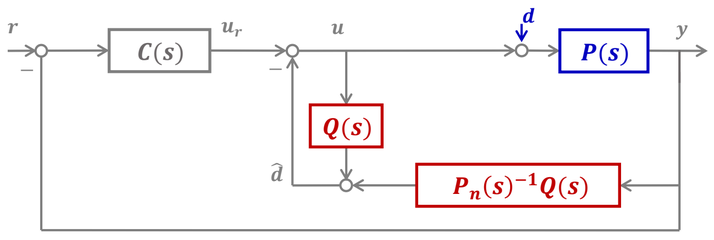
✓ **Type of attack and detection method**

- Zero-dynamics attack
- Replay attack
- Dos attack

- Multi-rate sampling
- Watermark Injection

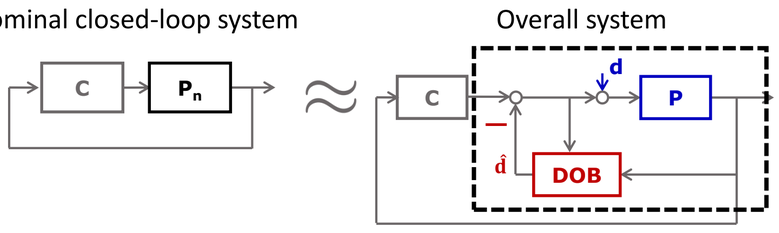
Disturbance Observer (DOB)

- Add-on type robust controller which makes a control input compensates for model errors and disturbances

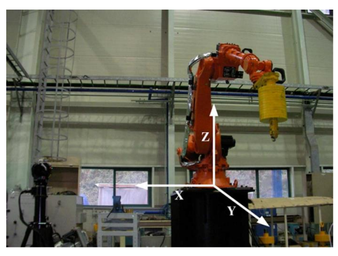


<A structure of DOB>

Nominal closed-loop system ≈ Overall system



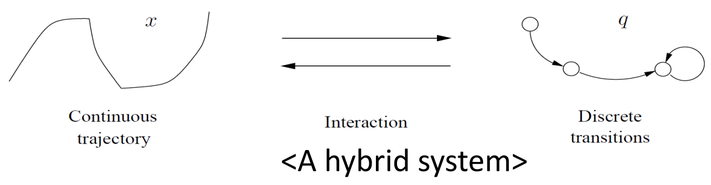
- Has many advantages over other robust control methods
- Inner-loop controller: enables modular design of controllers
- Has the benefit of design simplicity
→ employed in many industrial applications



< robot manipulator>

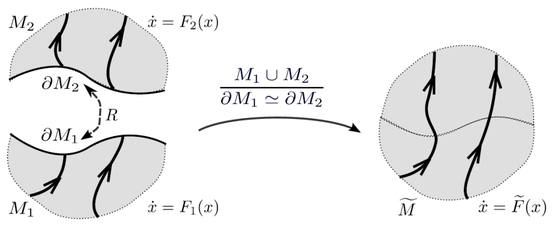
Hybrid System

- described by an interaction between continuous trajectory and discrete transition

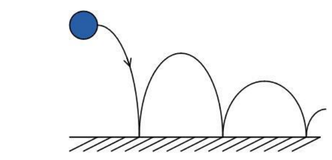


<A hybrid system>

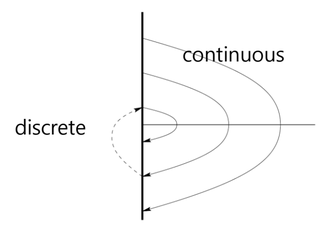
- **Gluing a domain** eliminates discrete transitions, to allow for easy analysis of hybrid system.



<Gluing a domain>



<Example: a bouncing ball>



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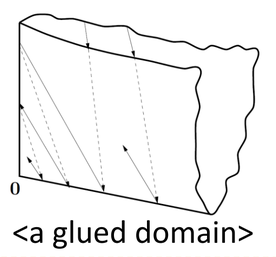
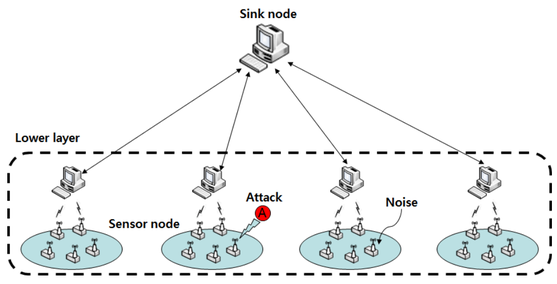


<a glued domain>

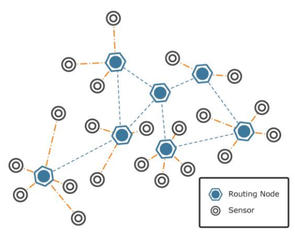
Sensor Network & Distributed Estimation

- Estimating the total state by the network of partial information, even though we can not see the full from each



<Exposed to noises and attacks>

- The sensor network is exposed to noises and malicious attacks, which should be covered

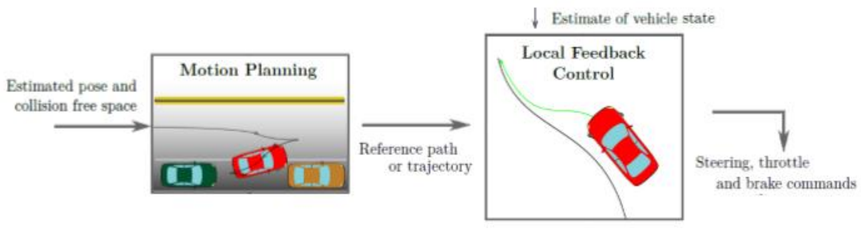


<Sensor network>

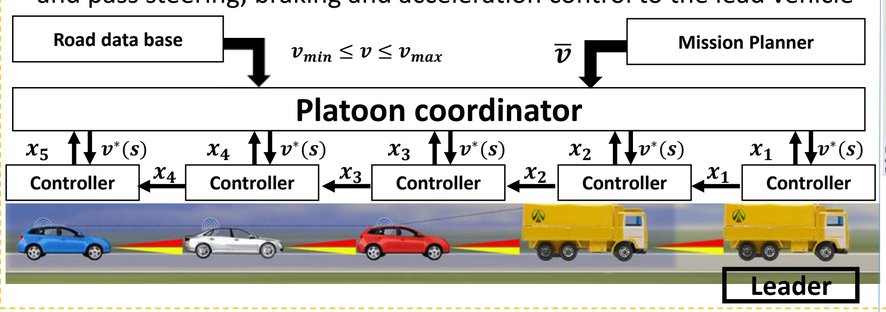
<Robust to attacks>

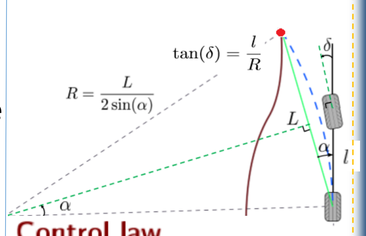
Vehicle Control

- **Path Stabilization Control :** calculates steering angle and throttle to decrease the distance error btw the path and vehicle



- **Platooning Control :** a group of vehicles play "follow the leader" and pass steering, braking and acceleration control to the lead vehicle





Control law

$$\delta = \tan^{-1}\left(\frac{2l\sin(\alpha)}{L}\right)$$

Example : Pure pursuit

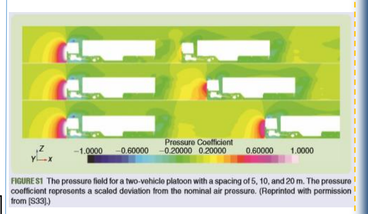


FIGURE S1 The pressure field for a two-vehicle platoon with a spacing of 5, 10, and 20 m. The pressure coefficient represents a scaled deviation from the nominal air pressure. (Reprinted with permission from [S33].)

Example : Air pressure according to distance

Q & A

? What we do

CDSL은 동역학과 제어에 관한 이론, 예를 들면 로봇 제어, 바이오 시스템 제어, 항공기 로켓 제어 등 dynamics와 feedback이 관계된 분야의 기본이 되는 이론을 개발하는 연구실입니다.

기계항공 전기전자 화학생물

Control theory

Mathematics

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

? Research on what

동적 시스템(dynamic system)을 제어(control)하는 법과 이 시스템의 상태를 추정하는 법을 연구합니다. 이에 더하여 불확실하거나 외란(disturbance)과 잡음(noise)의 영향을 받는 시스템도 같이 다룹니다.

? Research how

Dynamic system을 나타내는 수학 모델에서 출발하여 연구합니다. 이러한 모델은 수학 이론이 잘 적용될 수 있도록 실제 문제에서 핵심만 남긴 채 추상화 됩니다.

현실의 문제 → 수학 문제 (추상화, 간략화) → 문제 풀이 (이론 개발) → 수학 모델에 적용 및 검증 → 실제 문제에 적용 및 검증

? No experiment

실험은 과제와 관련된 예외적인 경우를 제외하고는 하지 않습니다. 그 대신 연구 내용은 시뮬레이션으로 검증합니다.

? Alumni

졸업 후의 진로는 다양합니다. 하지만, 다른 연구실에 비하여 많은 연구원 분들께서 academy를 희망하시며, 실제로 교원에 계시는 분들의 비율도 높습니다. CDSL은 그동안 100여명의 석사, 박사, 박사 후 연구원을 배출하였으며, 그 중 14명 이상이 현재 교수로 재직중이십니다.

? Necessity

연구실에서는 수학에 대한 관심과 소질 그리고 제어에 대한 관심이 있는 학생을 더 선호합니다. 선형대수와 제어공학개론이 가장 주요한 선수과목이라 할 수 있고, 공부한 내용을 얼마나 제대로 알고 있는가를 중요시 합니다. (working knowledge)

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