Fall 2021 (110-1)

控制系統
Control Systems

Unit 1B
Introduction - Feedback and Control

Feng-Li Lian

NTU-EE

Sep 2021 – Jan 2022

Mobile Robots, Autonomous Driving Vehicles

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http://hompage.ntu.edu.tw/~fengli/Research

- Google Self-Driving Cars in 2014

Source: https://youtu.be/TsaES--OTzM Time: 1:03 – 8:37

Mobile Robots, Autonomous Driving Vehicles

- 2020年的交通與生活 Toyota e-Palette

Source: https://www.youtube.com/watch?v=XmoPQuMlOYE
https://www.servicejdc.com/product/blog/item/60-20181015.html

Unmanned Arial Vehicles (UAV)

- Olympic Winter Games by Intel
- 2,000 Drones in Shanghai to Welcome New Year
- 2020 義大世界跨年夜《400台無人機視覺超震撼》
- 2020 台灣燈會無人機展演

https://youtu.be/eIk6j6dprnA

https://youtu.be/v05uHuJj7Hs

https://youtu.be/XS--SQMUeUY

https://youtu.be/XTUS3cfKUuc

https://news.ltn.com.tw/news/life/breakingnews/3077228

Three Layers of Control Tasks

- Top Layer:
  - For Multiple Agents (Group of Vehicles, Cars, Drones)

https://images.app.goo.gl/Zvqbjf3nsAFoLBFK8

https://images.app.goo.gl/FjoqLo13CQ8o4v83A

https://images.app.goo.gl/A9yhHUUEsoJKWPLj9

https://images.app.goo.gl/ErUGddRBXwdwr2b17

- Action:
  - 方向盤
  - 油門煞車
- Goal:
  - 位置/車道
  - 速度/方向

Three Layers of Control Tasks

Middle Layer:

- For Single Agent (Single Vehicle, Car, Drone)

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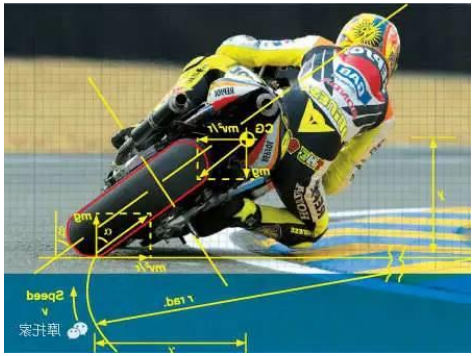
https://images.app.goo.gl/9MnAPBzcBDJcpxiQ6



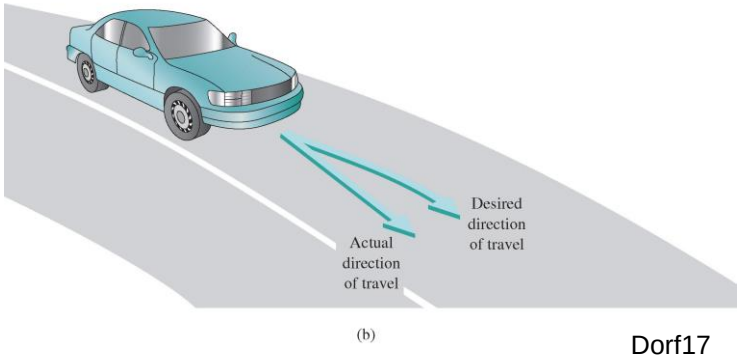
https://images.app.goo.gl/5p7G4g19ZayMYkb28

https://images.app.goo.gl/GzScsbcFTDPsaApJ8

- Action:
  - 統整四個輪子
  - 統整四個螺旋槳
- Goal:
  - 方向
  - 加減速

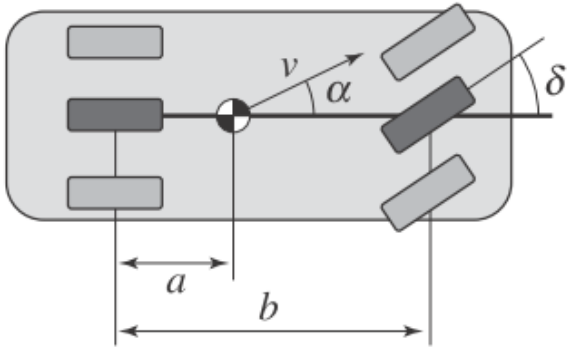
Three Layers of Control Tasks

- ## Middle Layer:
  - ### For Single Agent (Single Vehicle, Car, Drone)

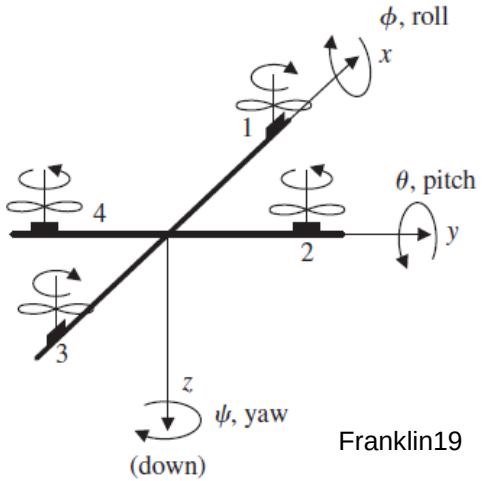


Dorf17

Franklin19



Astrom19

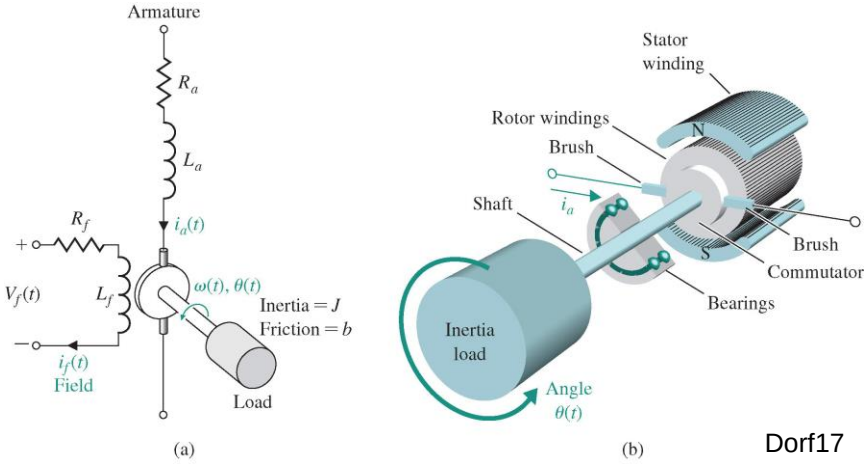


Franklin19

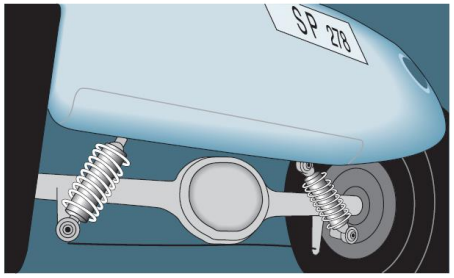
- Action:
  - 統整四個輪子
  - 統整四個螺旋槳
- Goal:
  - 方向
  - 加減速

Three Layers of Control Tasks

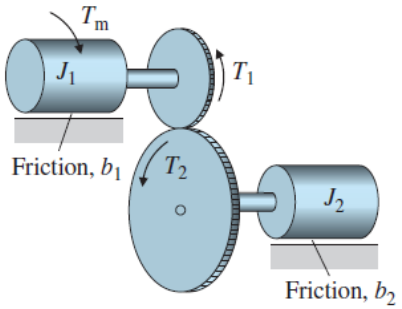
- **Bottom Layer:**
  - For Subsystems (Wheel, Motor, Engine, Gear Box, Braking)



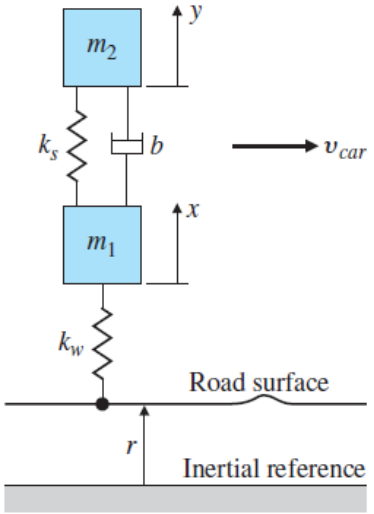
Dorf17



Franklin19



Franklin19



Franklin19

- **Action:**
  - 控制驅動電流/電壓
- **Goal:**
  - 每一個輪子/螺旋槳的轉速/轉角

Three Layers of Control Tasks

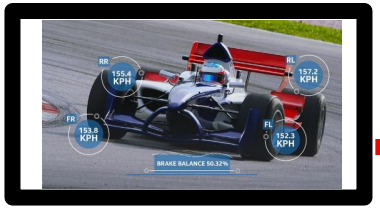
- **Top Layer:**
  - For Multiple Agents (Group of Vehicles, Cars, Drones)

➢ 方向盤
➢ 油門煞車

➢ 位置/車道
➢ 速度/方向

- **Middle Layer:**
  - For Single Agent (Single Vehicle, Car, Drone)

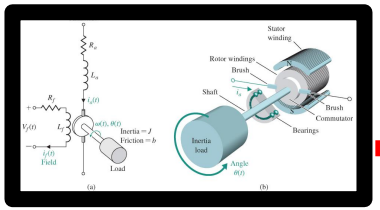
➢ 統整四個輪子
➢ 統整四個螺旋槳



➢ 方向
➢ 加減速

- **Bottom Layer:**
  - For Subsystems (Wheel, Motor, Engine, Gear Box, Braking)

➢ 控制驅動電流/電壓



➢ 每一個輪子/螺旋槳的轉速/轉角

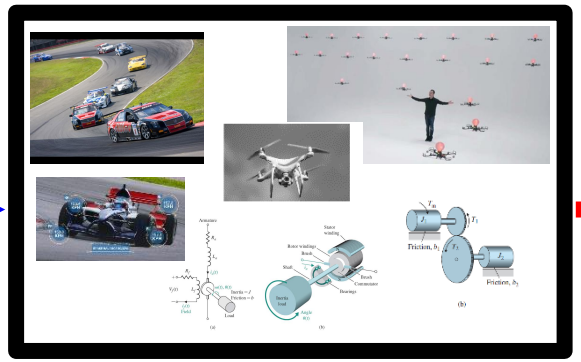
Plant, Input, Output, Action, Goal

Signals & Systems

Control Systems

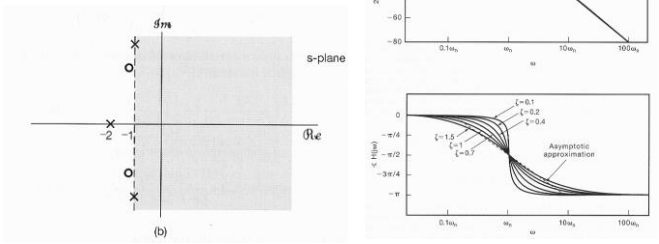
1. Model
2. Response
3. Analysis
4. Feedback
5. Control

Ref (r) → Input (u) → **Plant (P)** → Output (y)



$$\frac{d^2y(t)}{dt^2} + 2\frac{dy(t)}{dt} - 3\,y(t) = 5\,u(t)$$

$$P(s) = \frac{Y(s)}{U(s)} = \frac{5}{s^2 + 2s - 3}$$



Controller

$$\frac{d^2y(t)}{dt^2} + 4\frac{dy(t)}{dt} + 3\,y(t) = 3\,r(t)$$

$$G(s) = \frac{Y(s)}{R(s)} = \frac{3}{s^2 + 4s + 3}$$

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Plant, Input, Output, Action, Goal

Cyber

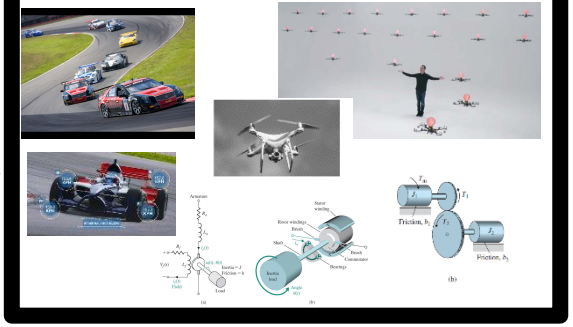
Controller

System Identification

Plant (P)
Computer

Path Planning
Trajectory Generation

Plant (P)



Ref (r)

Input (u)

Output (y)

PID Design
Compensation

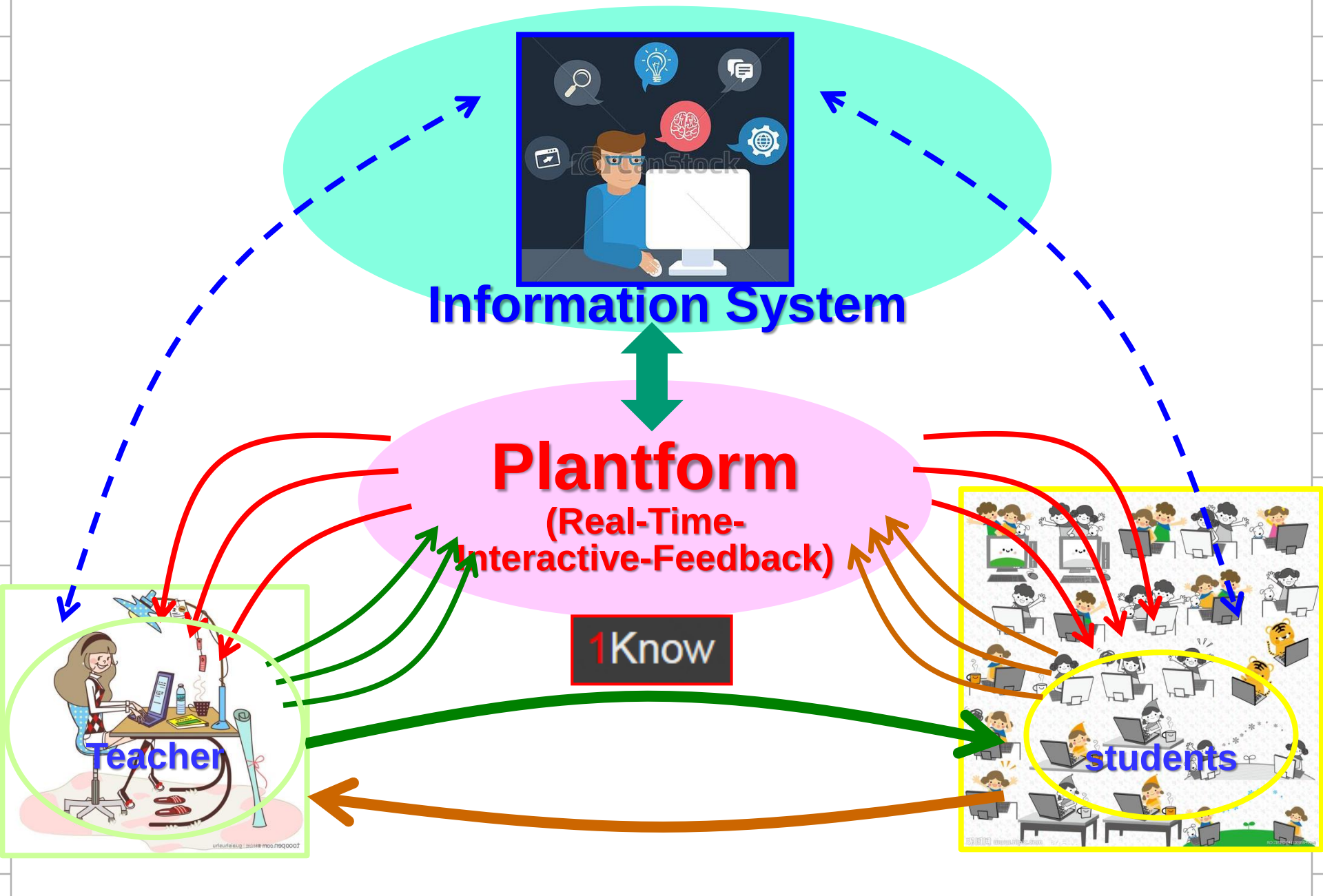
Controller

Physical

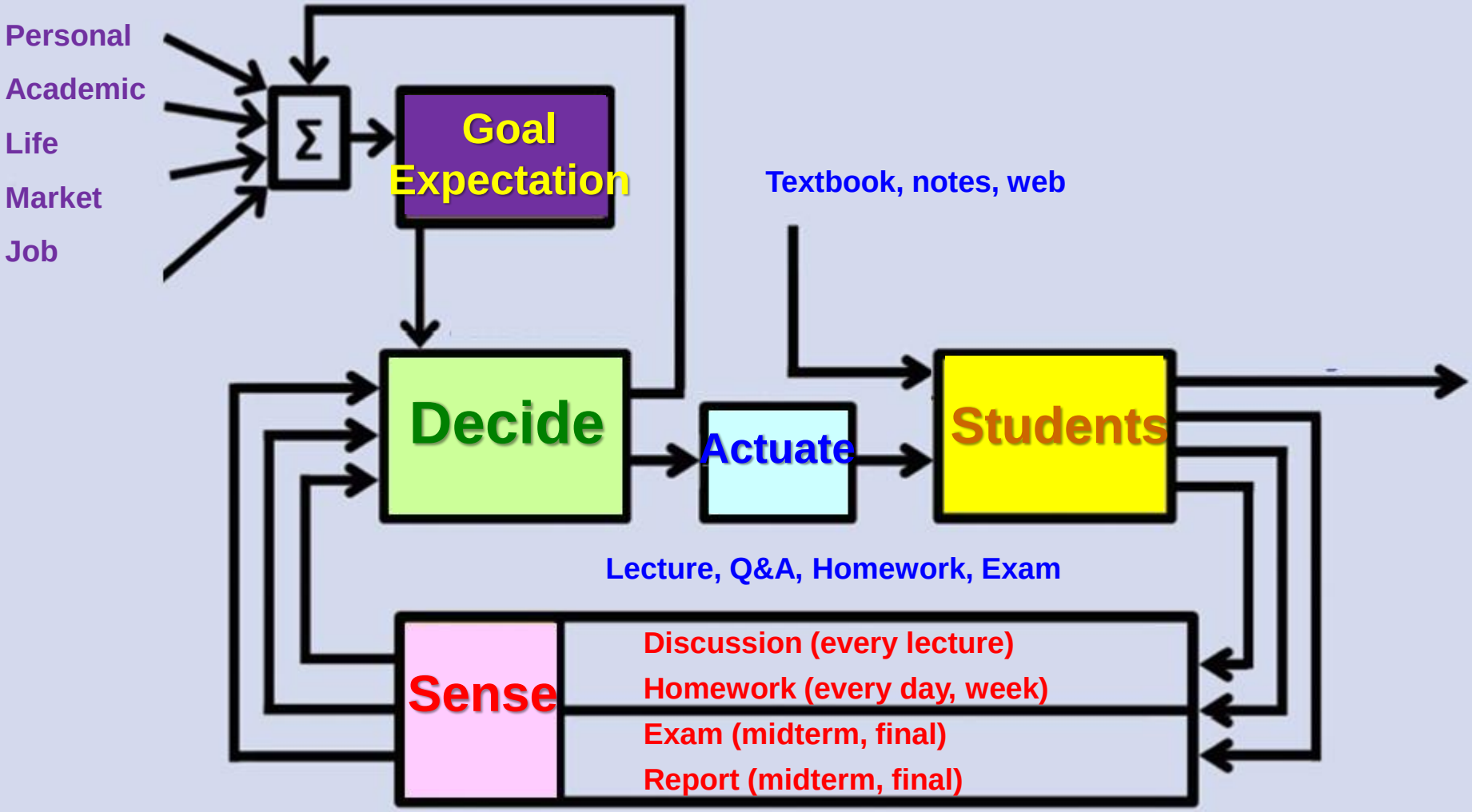
Feedback and Control in Teaching and Learning

Teacher

Students


Information System
Plantform
(Real-Time-
Interactive-Feedback)
1Know
Teacher
students

Feedback and Control in Teaching and Learning



Source：IEEE CSM 2013

Control vs Non-Control

- CoViD – 19（新型冠狀病毒肺炎）
- 口罩自動化生產系統

- 主要變數（信號）：
  - 所需的口罩數量
  - 生產原料種類與數量
  - 每一片口罩生產所需的時間
  - 單位時間產量的良率
  - 整體的產能等等等

- 系統：
  - 備料
  - 分批
  - 組裝
  - 包裝
  - 傳送
  - 旋轉
  - 擠壓

https://youtu.be/DCee9sSA_mY
https://youtu.be/UB0gEHqc1GI

Control vs Non-Control

- CoViD – 19（新型冠狀病毒肺炎）
- 即時口罩地圖 https://mask.goodideas-studio.com/

udn / 信讀家 / 新社會

看見我科技實力！唐鳳：多國對台灣口罩地圖有興趣

2020/02/18 張文馨

行政院政務委員唐鳳受華府智庫邀請訪問美國，他14日在駐美代表處分享此行訪問經驗；被問到新冠肺炎（COVID-19）在台灣造成口罩搶購，唐鳳說，台灣藉此機會實作開放政府，把原始碼放在網路上成立口罩地圖，引起美國等國家的興趣，他們都可以直接在網路上看到這次實作過程。

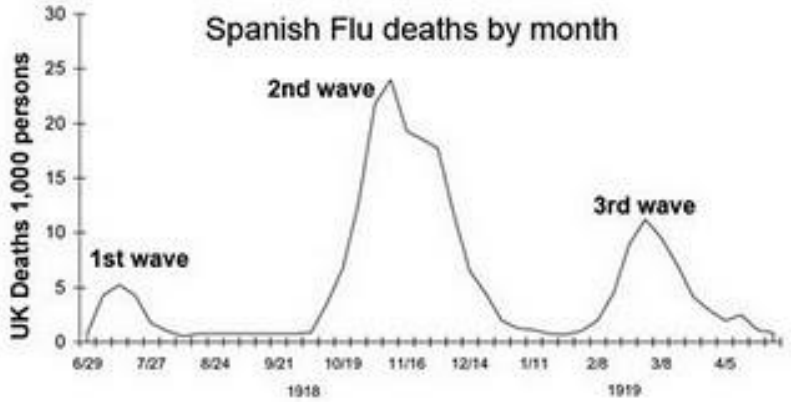
行政院政務委員唐鳳。 圖 / 黃仲裕攝影

唐鳳指出，此行也有和美國國會與行政機關官員互動，和美國國會眾議院物聯網連線的主席、金融服務小組委員會、人工智慧任務小組主席，以及行政機關的數位任務小組成員都到訪體不輕，話題聚焦開放政府，唐鳳稱，與行政官員深入交換意見，並商討可以如何合作。

- 主要變數（信號）：
  - 販賣處的位置（距離）
  - 販賣時間（絕對時間點，持續時間）
  - 口罩存量（與時間的關係式）
  - 口罩種類
- 系統：
  - 排隊
  - 分包
  - 交通時間
  - 運送時間

Control vs Non-Control

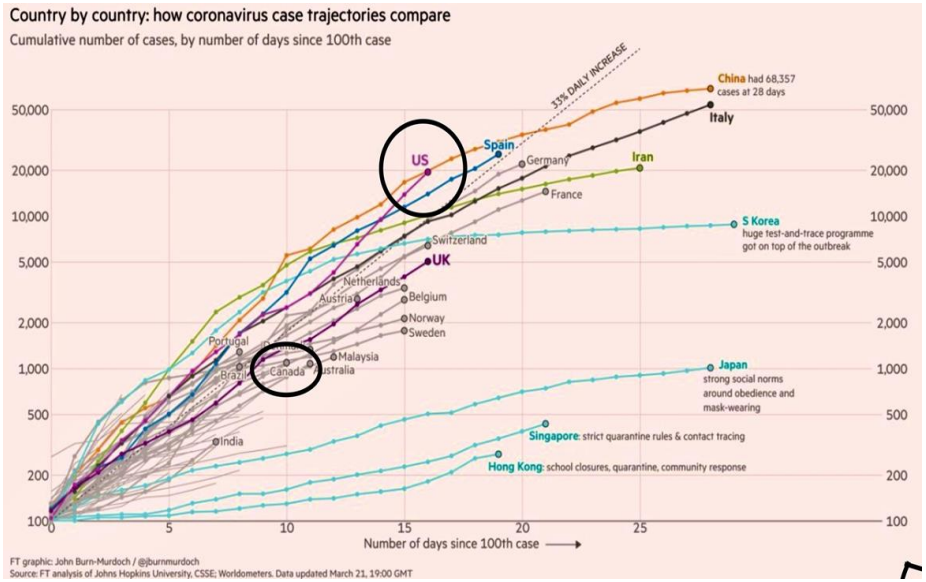
- CoViD – 19（新型冠狀病毒肺炎）
- 1918年西班牙流感大流行

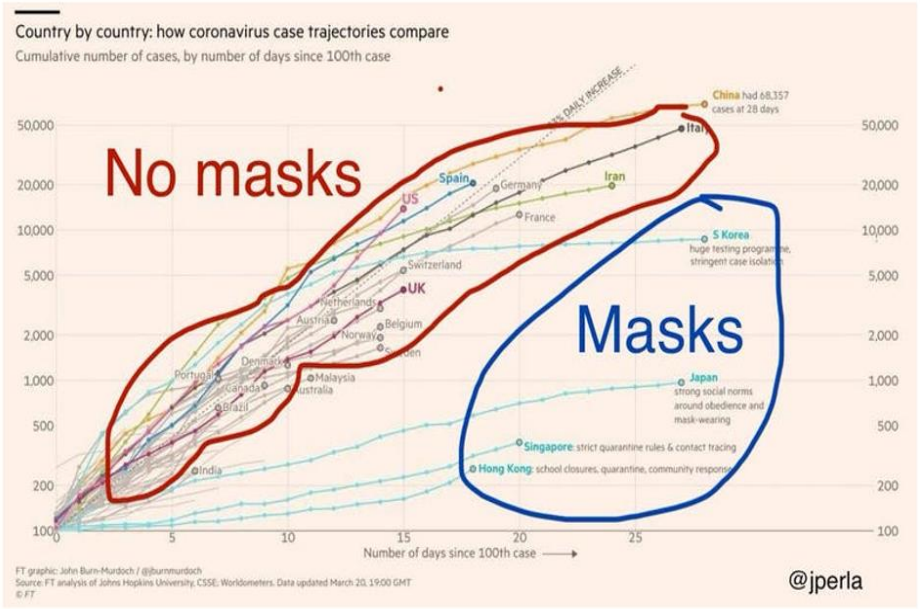


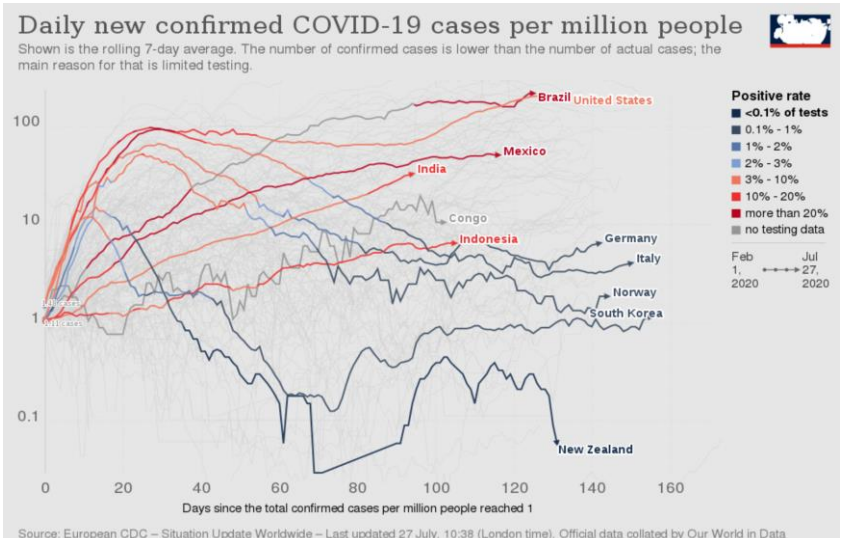
- 主要變數（信號）：
  - 確診人數 vs 不同時間點
  - 死亡人數 vs 不同時間點
  - 產生抗體人數 vs 不同時間點
  - 醫療數量，位置，品質，效能
- 系統：
  - 感染機制
  - 治療機制
  - 隔離機制

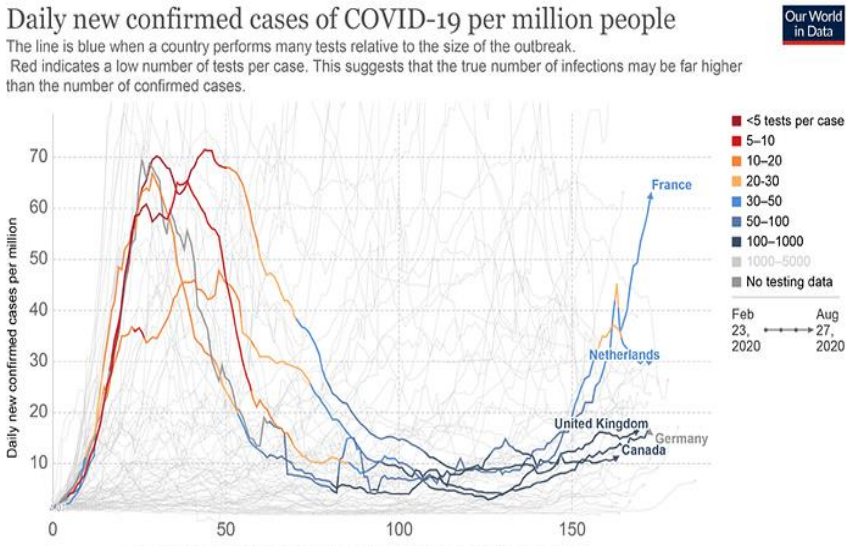
Control vs Non-Control

- CoViD – 19（新型冠狀病毒肺炎）
- 2019年新型冠狀病毒肺炎大流行





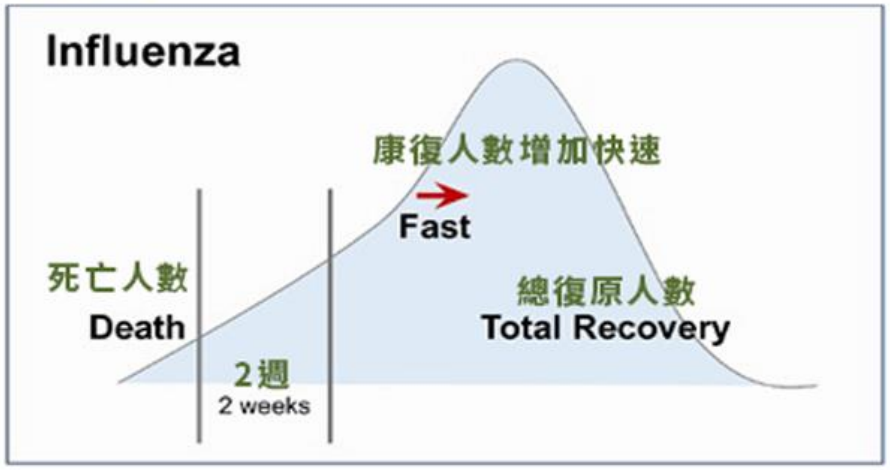




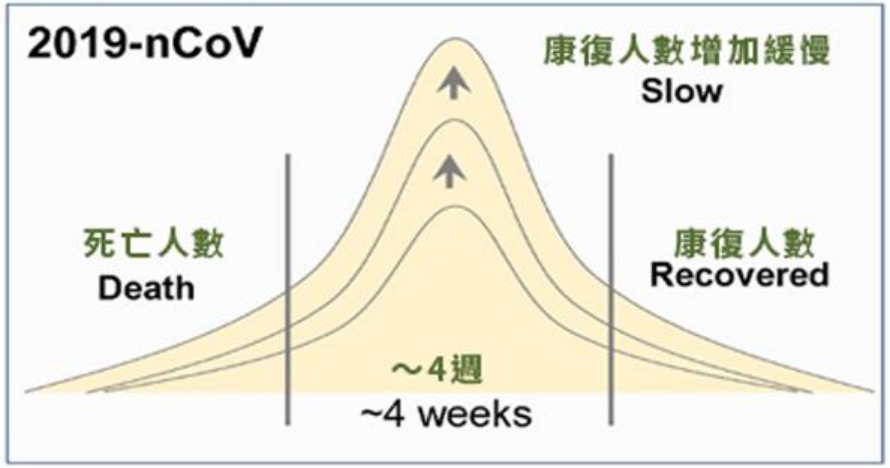
Control vs Non-Control

- CoViD – 19（新型冠狀病毒肺炎）
- 馬偕醫學院 學務長 張南驥教授

流感

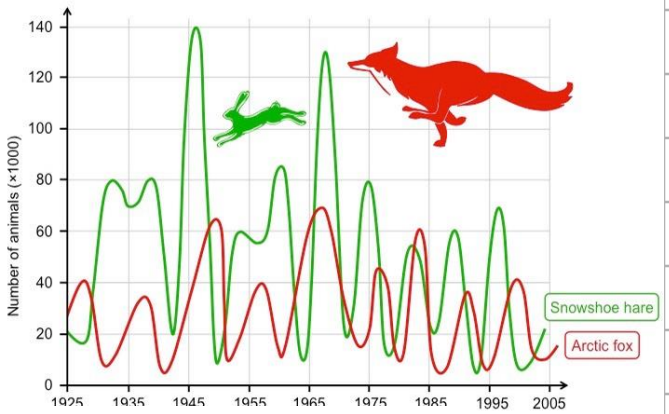


武漢肺炎

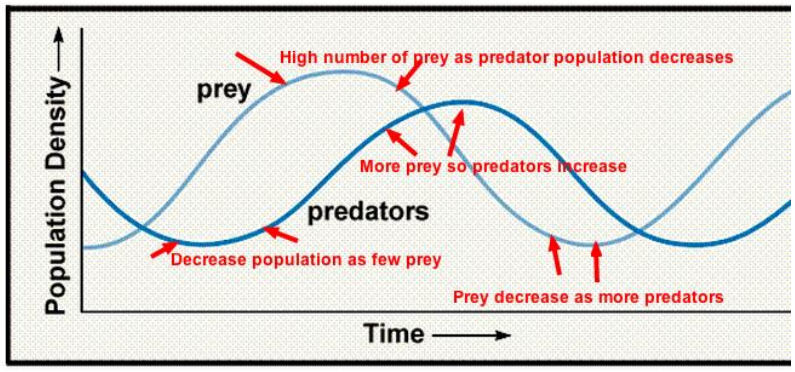


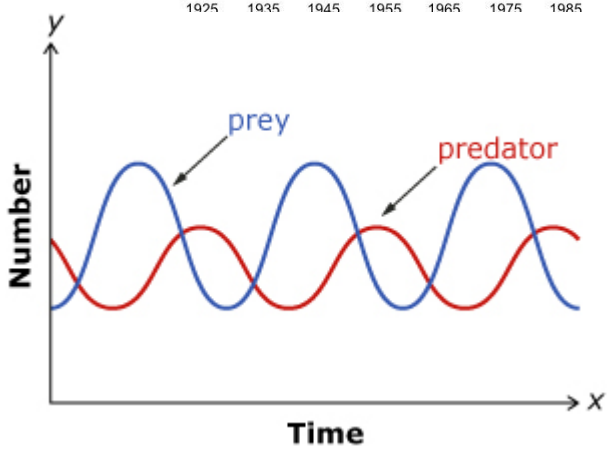
Control vs Non-Control

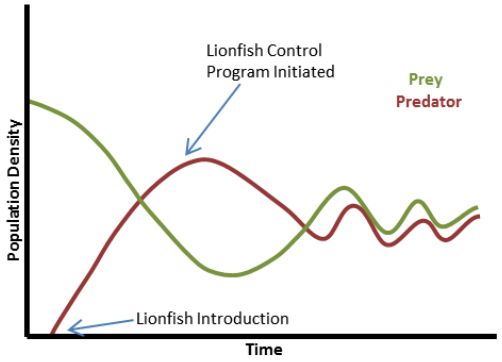
- Prey-Predatory（兔子與狐狸）



Sylvia S Mader, Biology, 6th edition. © 1998 The McGraw-Hill Companies, Inc. All rights reserved.







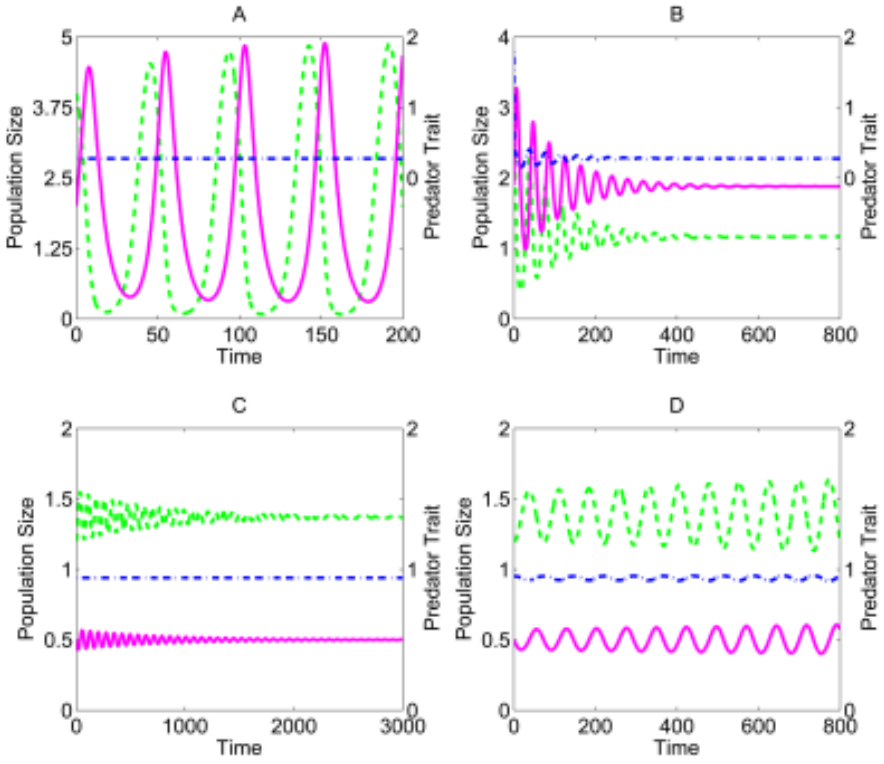
Control vs Non-Control

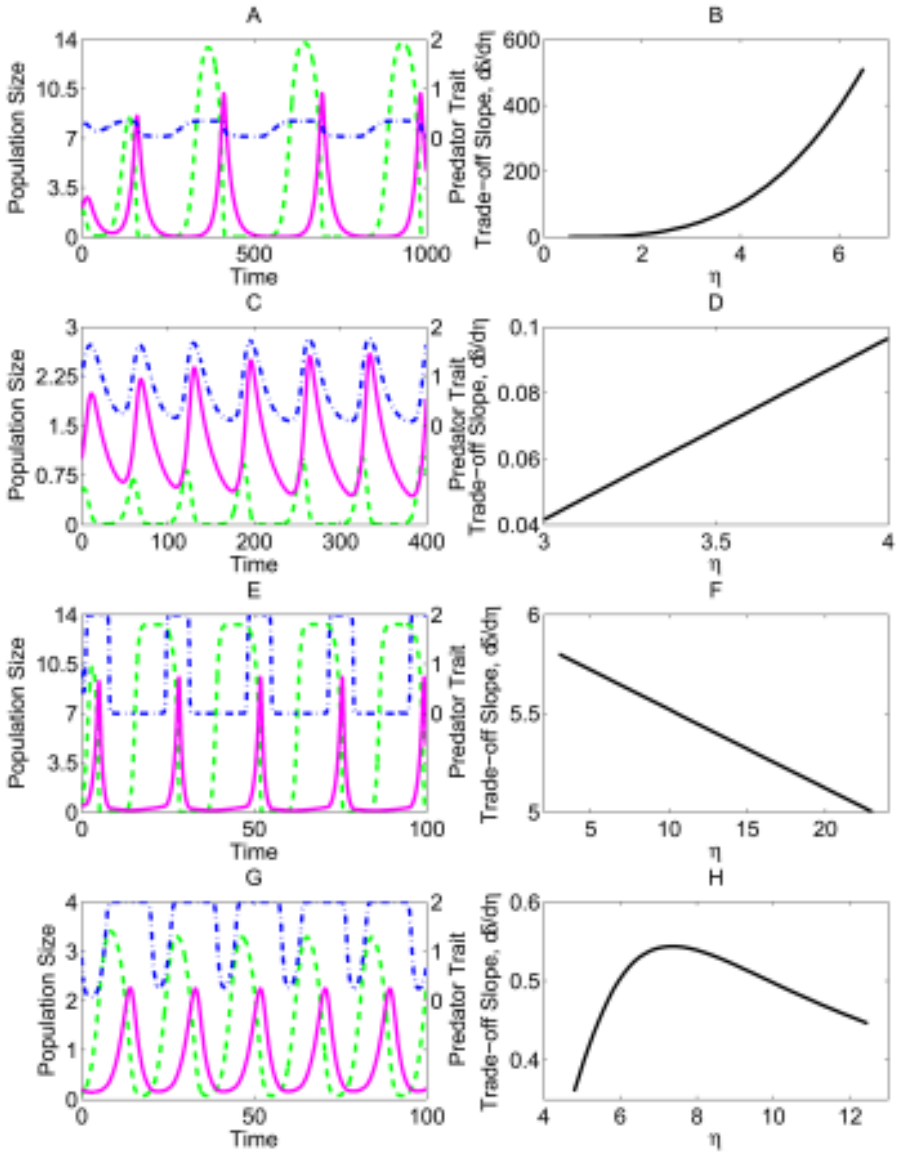
- Prey-Predatory（兔子與狐狸）

vol. 176, no. 5 the american naturalist november 2010
E-Article

Understanding Rapid Evolution in Predator-Prey Interactions Using the Theory of Fast-Slow Dynamical Systems

Michael H. Cortez[1,*] and Stephen P. Ellner[1,2]





Control vs Non-Control

- Prey-Predatory（兔子與狐狸）

Resilience Modeling by Means of a Set of Recursive Functions.

Maria Teresa Signes Pont, Juan Manuel García Chamizo, Higinio Mora Mora, Jerónimo Mora Pascual
Departamento de Tecnología Informática y Computación
Universidad de Alicante
03690 San Vicente del Raspeig - Alicante, España
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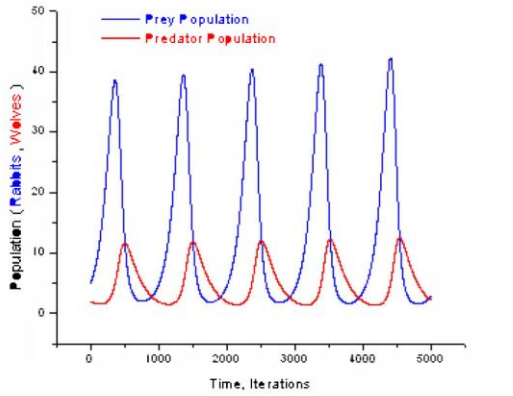
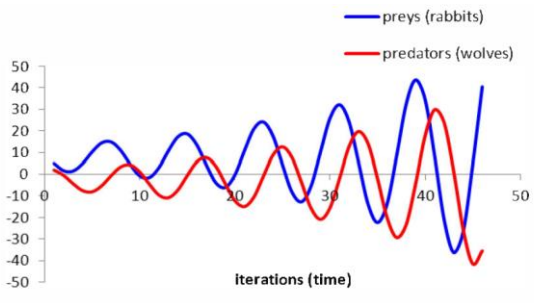
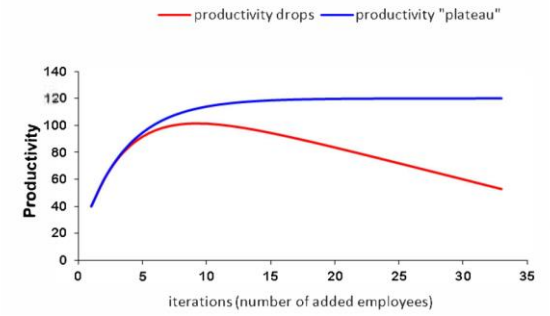
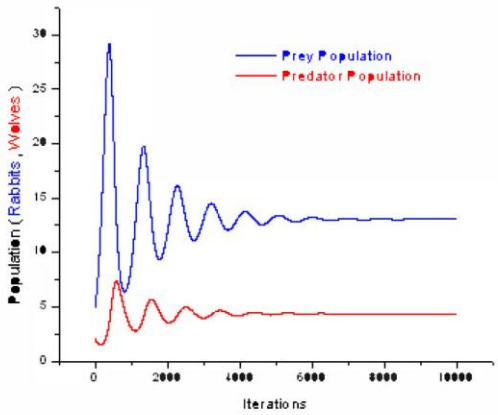
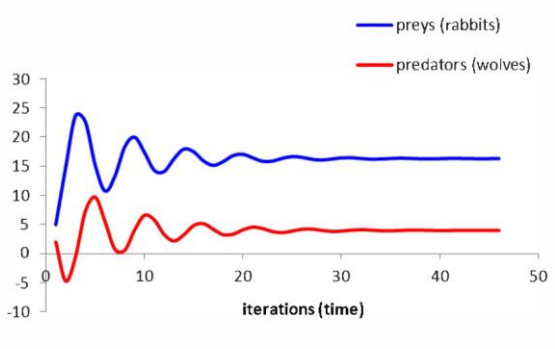
978-1-4799-0181-4/13/$31.00 ©2013 IEEE

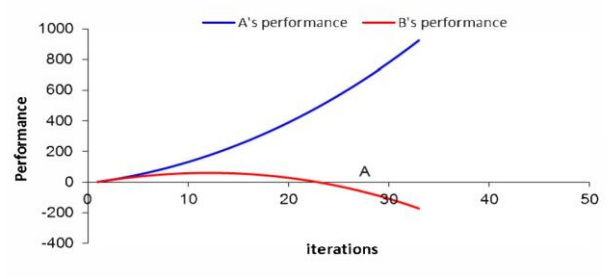


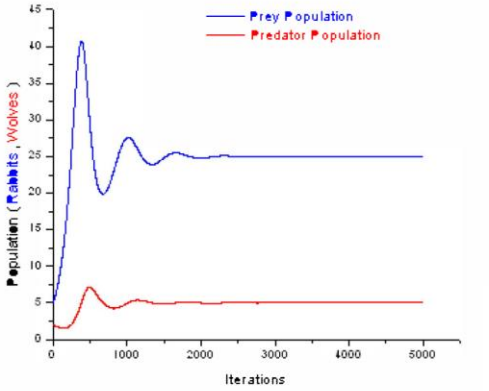


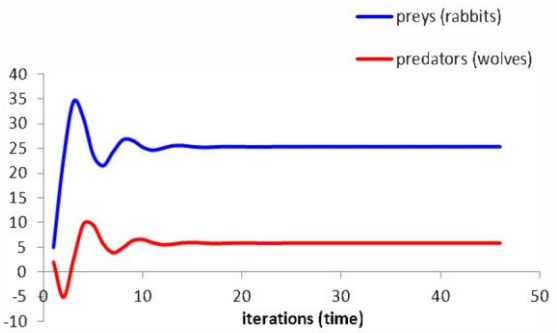




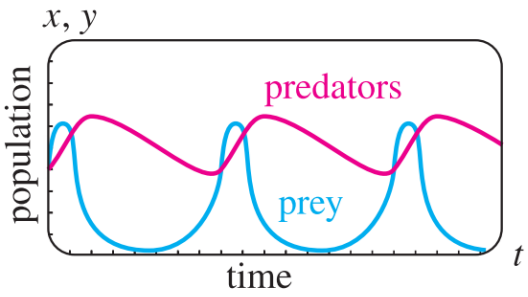






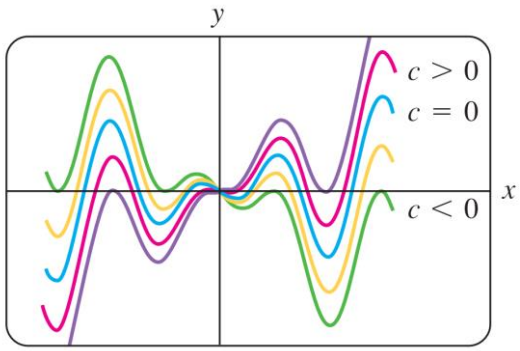


Understand the System by Differential Equations



$$\frac{dx}{dt} = -0.16x + 0.08xy$$

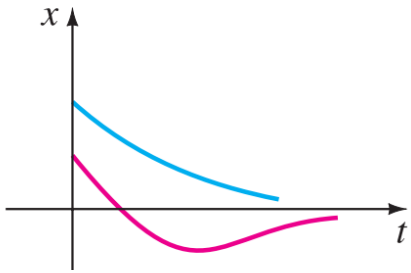
$$\frac{dy}{dt} = 4.5y - 0.9xy$$

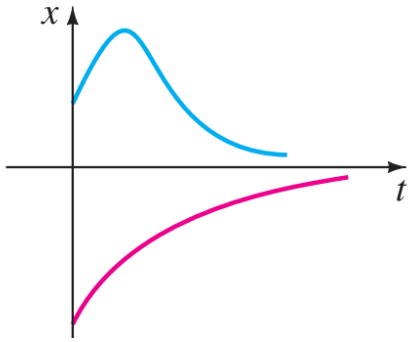


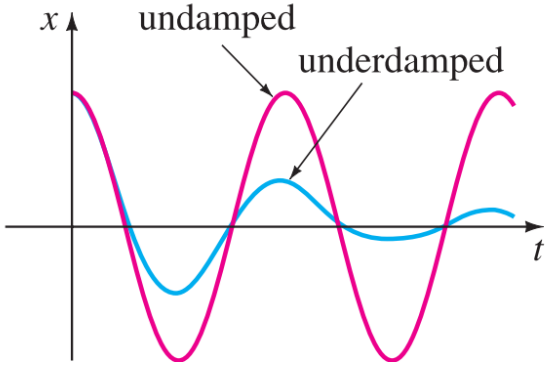
$$xy' - y = x^2 \sin x$$

$$y = cx - x\cos x$$

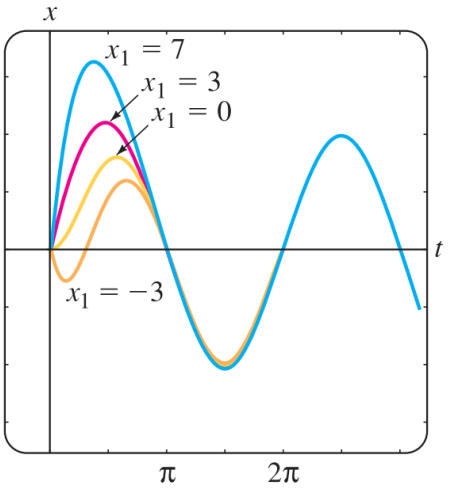
$$\frac{d^2x}{dt^2} + 2\lambda\frac{dx}{dt} + \omega^2 x = 0,$$

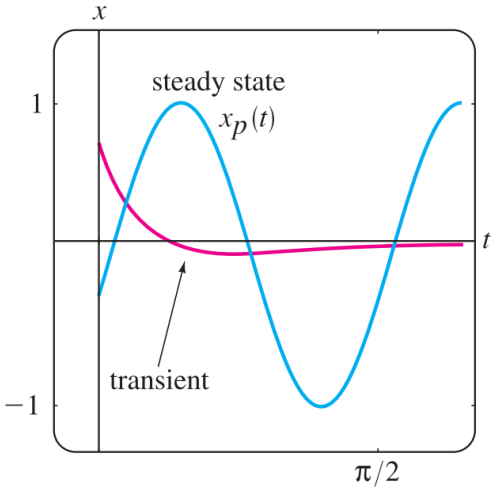






$$\frac{d^2x}{dt^2} + 2\lambda\frac{dx}{dt} + \omega^2 x = F(t),$$





Key Terminologies in Feedback and Control

- Manual Control
- Automatic Control

- Open-Loop Control
- Closed-Loop Control or Feedback Control

- Regulation
- Tracking or Servo System

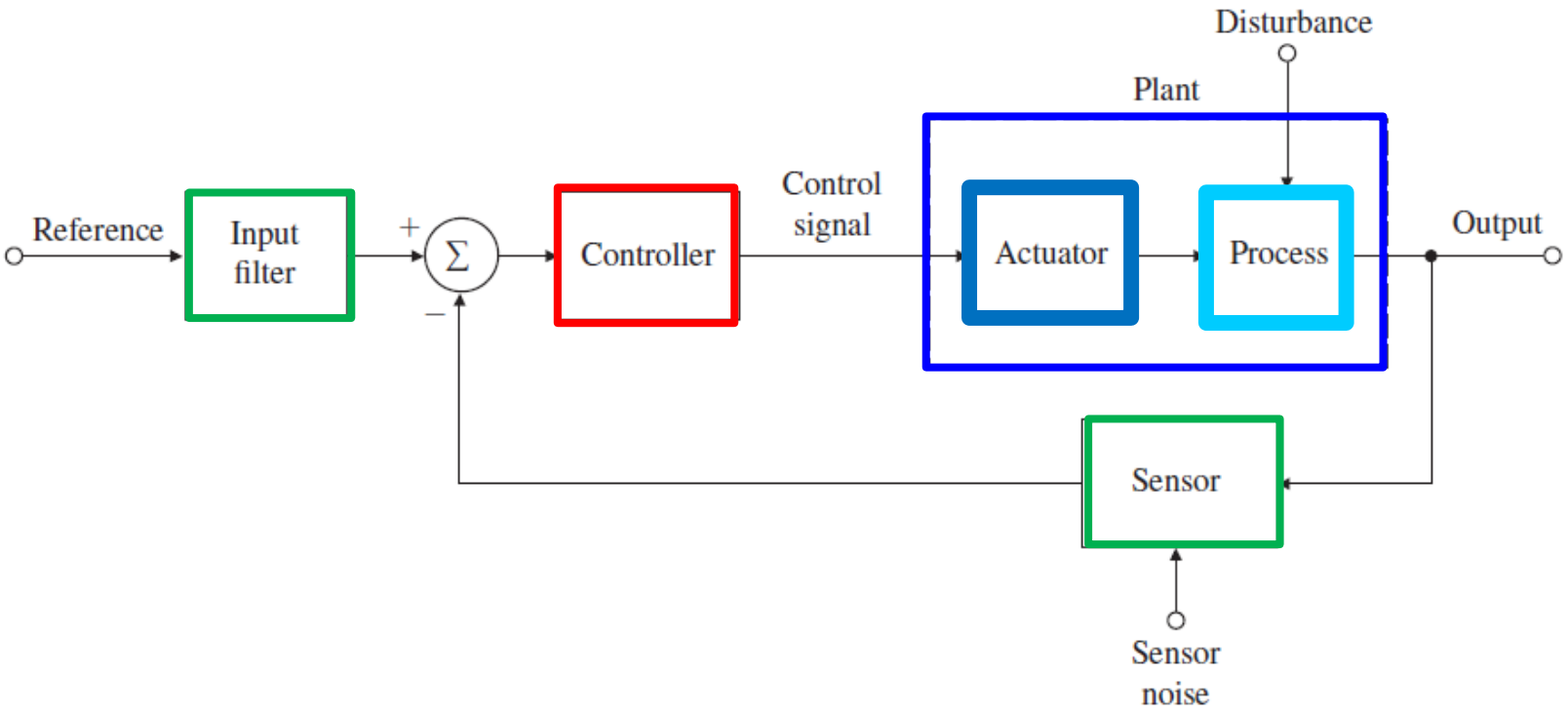
- Feedback
- Feedforward
- Control as a hidden technology

- Systems, Subsystems, Signal/Information Flow
- Process, Plant,
  Actuator, Sensor, Filter, Controller, Compensator

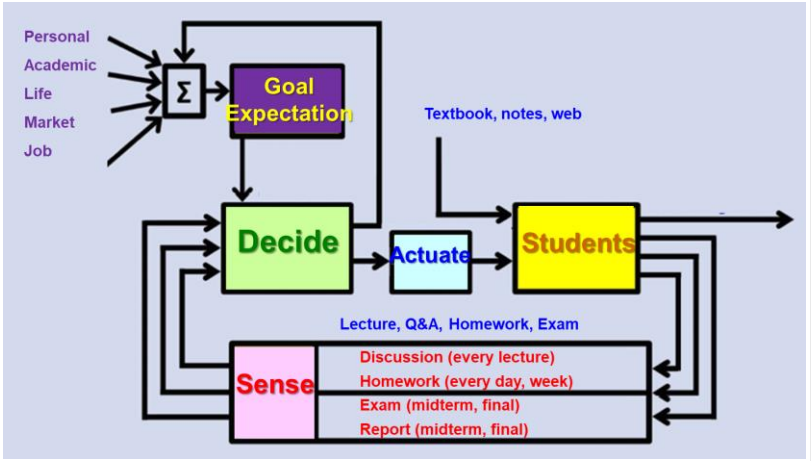
Key Terminologies in Feedback and Control

- Goals:
  - Stability
  - Tracking
  - Disturbance Rejection
  - Robustness
- Classic Control
- Modern Control

Key Terminologies in Feedback and Control



- **Modeling**: the plant
- **Analysis**: the plant
- **Design**: the controller for the plant



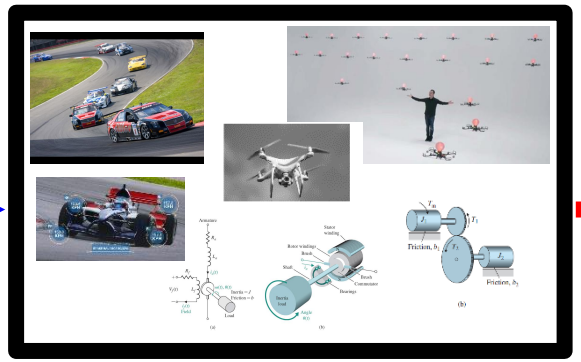
Plant, Input, Output, Action, Goal

Signals & Systems

Control Systems

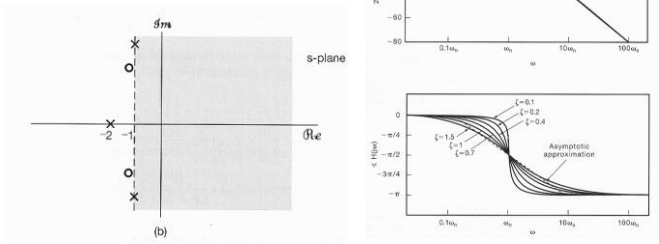
1. Model
2. Response
3. Analysis
4. Feedback
5. Control

Ref (r) → Input (u) → **Plant (P)** → Output (y)



$$\frac{d^2y(t)}{dt^2} + 2\frac{dy(t)}{dt} - 3\,y(t) = 5\,u(t)$$

$$P(s) = \frac{Y(s)}{U(s)} = \frac{5}{s^2 + 2s - 3}$$

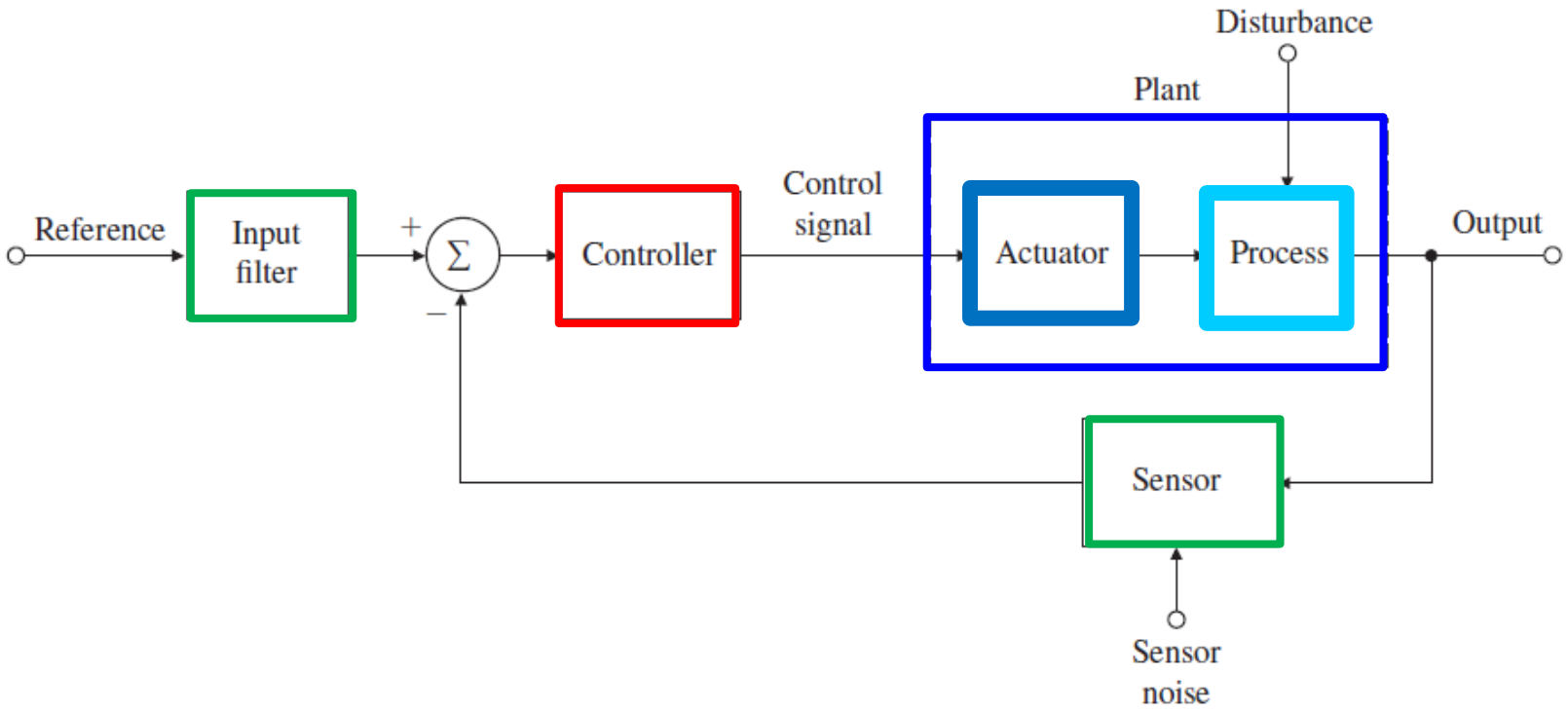


Controller

$$\frac{d^2y(t)}{dt^2} + 4\frac{dy(t)}{dt} + 3\,y(t) = 3\,r(t)$$

$$G(s) = \frac{Y(s)}{R(s)} = \frac{3}{s^2 + 4s + 3}$$

Key Terminologies in Feedback and Control



Control vs Non-Control

- AlphaGo（圍棋）
- 人的手下棋

- 機械手下棋