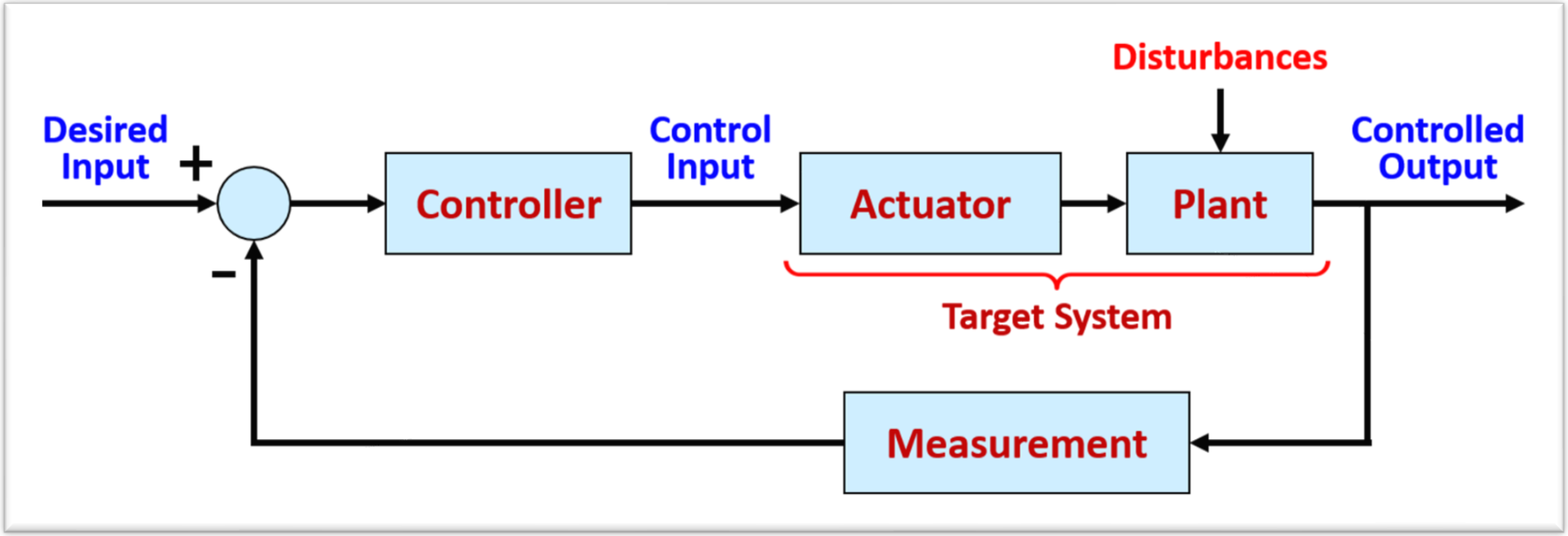
Class Overview and Important Concepts

Lecture 1:

- Course Information
- Overview of Control Systems & Engineering



Prof. Seunghoon Woo

Department of Automotive Engineering | College of Automotive Engineering

KOOKMIN UNIVERSITY

https://youtu.be/0iLxfEeMEi0?list=RDCMUCkGHfaOvdHxoqftxHTCEsqg

Instructors

- **Class Instructor: Prof. Seunghoon Woo**
  - Associate Professor @ Dept. of Automotive Engineering
  - Office: W1 532, boltra@kookmin.ac.kr
  - Website: https://ivdc.kookmin.ac.kr

Course Information

❖ Textbook:

- Dorf, R.C.; Bishop, R.H. *Modern Control Systems*; Pearson, 2017.

  (Currently 13th edition is out, but previous versions are also available)
- Download PDF file @ eCampus. If any typo errors, please let me know.

Weekly Schedule

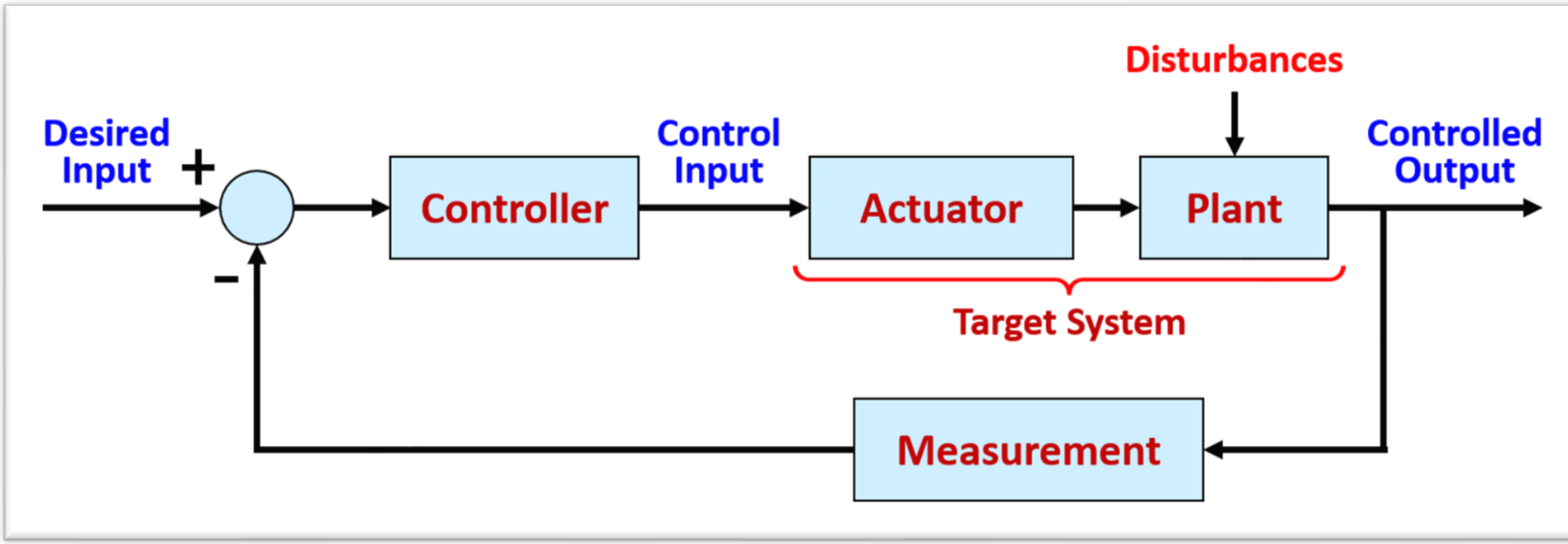
Days	Contents
Day 1	Important Concepts, Dynamic Models
Day 2	Dynamic Response
Day 3	Analysis of Feedback
Day 4	The Root-Locus Design Method
Day 5	The Frequency-Response Design Method

Any Questions From Students??

Class Overview and Important Concepts

Lecture 1:

- Course Information
- Overview of Control Systems & Engineering



Prof. Seunghoon Woo

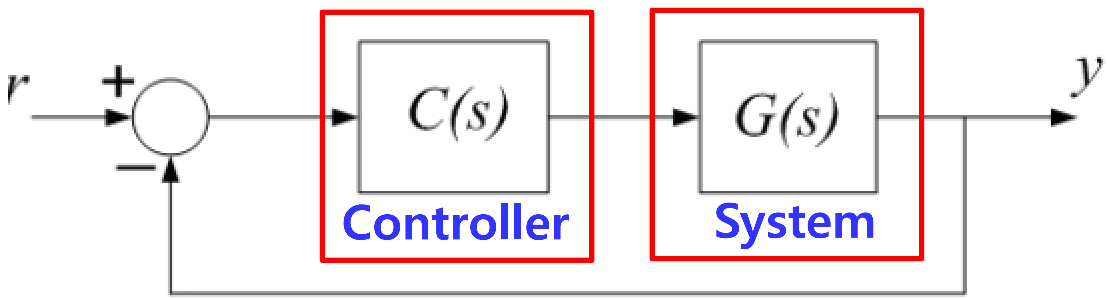
Department of Automotive Engineering | College of Automotive Engineering

KOOKMIN UNIVERSITY

What is “Control (제어)” ??

VS.

Desired Input(r)

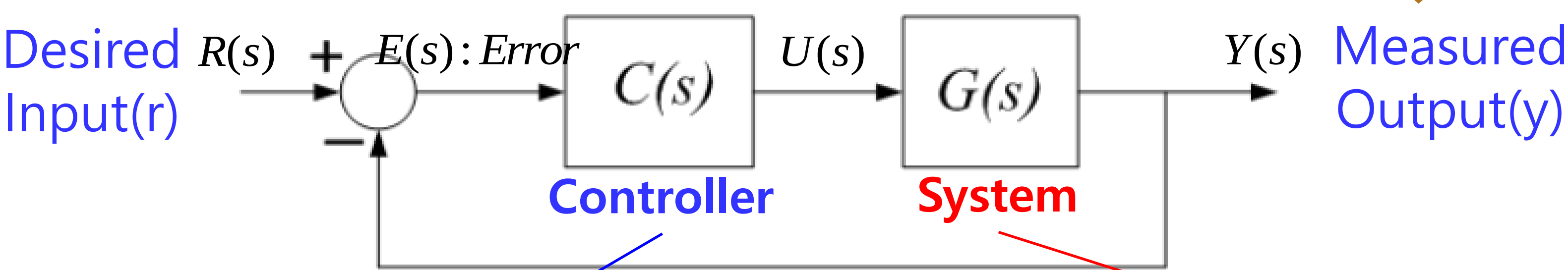


Measured Output(y)

- First, check about what the system is !! → **Modeling**
- Controller is to minimize error between the desired input (dream) between the measured output (reality) !! → **Design Controller**

What is "Control (제어)" ??

VS.



$U(s) = k_p \cdot E(s) + k_i \int E(s)ds + k_d \dfrac{dE(s)}{ds}$: PID Control
Typical Controller Example : PID Control

$G(s) = \dfrac{s^m + b_{m-1}s^{m-1} \ldots + b_1 s + b_0}{s^n + a_{n-1}s^{n-1} \ldots + a_1 s + a_0}$
Generalized System Example

What is “Control (제어)” ??

- Make some object (called **System** or **Plant**) behave as we desire.

- Imagine “Control” around you !!
  - Room temperature control
  - Car/bicycle driving
  - Voice volume control
  - “Control” (move) the position of the pointer
  - Cruise control or speed control
  - Process control
  - etc.

What is “Control (제어)” ??

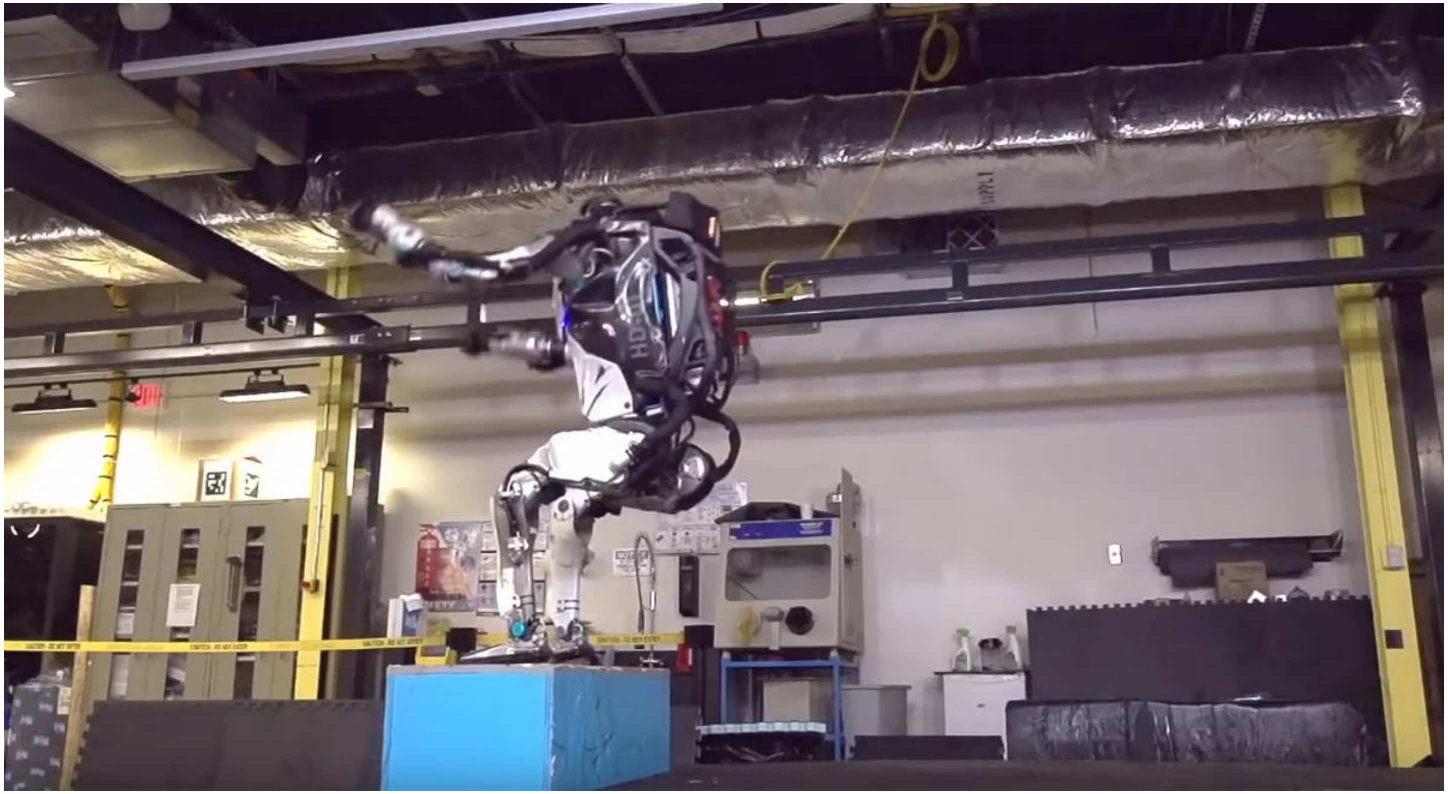
❖ Why do we need control systems?

- Convenient (room temperature control, laundry machine)
- Dangerous (hot/cold places, space, bomb removal)
- Impossible for human (nanometer scale precision positioning, work inside the small space that human cannot enter)
- It exists in nature. (human body temperature control)
- Lower cost, high efficiency, etc…

❖ Many examples of control systems around us !!

Robotic Control Systems in USA

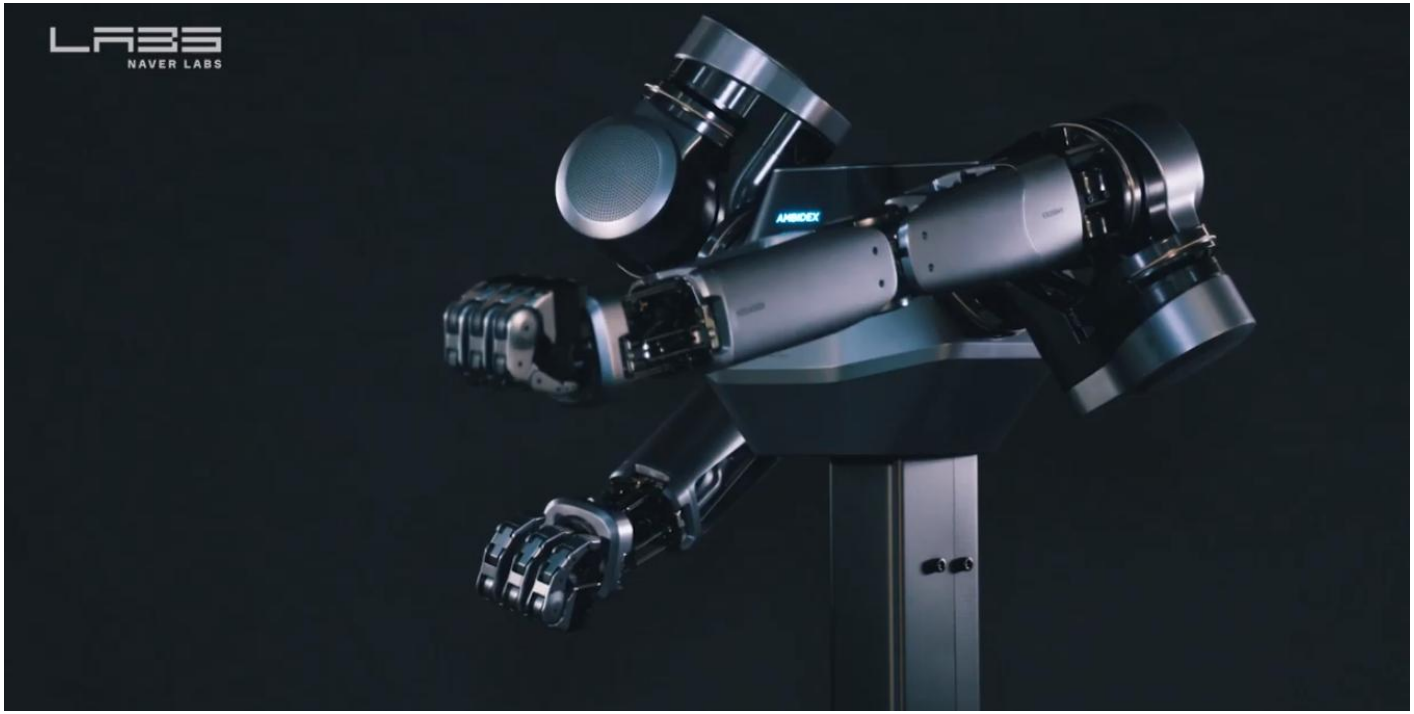
❖ **Boston Dynamics: Atlas (2017년)**



https://www.youtube.com/watch?v=SELVa0jsGkE

Robotic Control Systems in KOREA

❖ Naver Labs: AMBIDEX



https://www.youtube.com/watch?v=BRpUcKsvr4I

Autonomous Vehicle Control

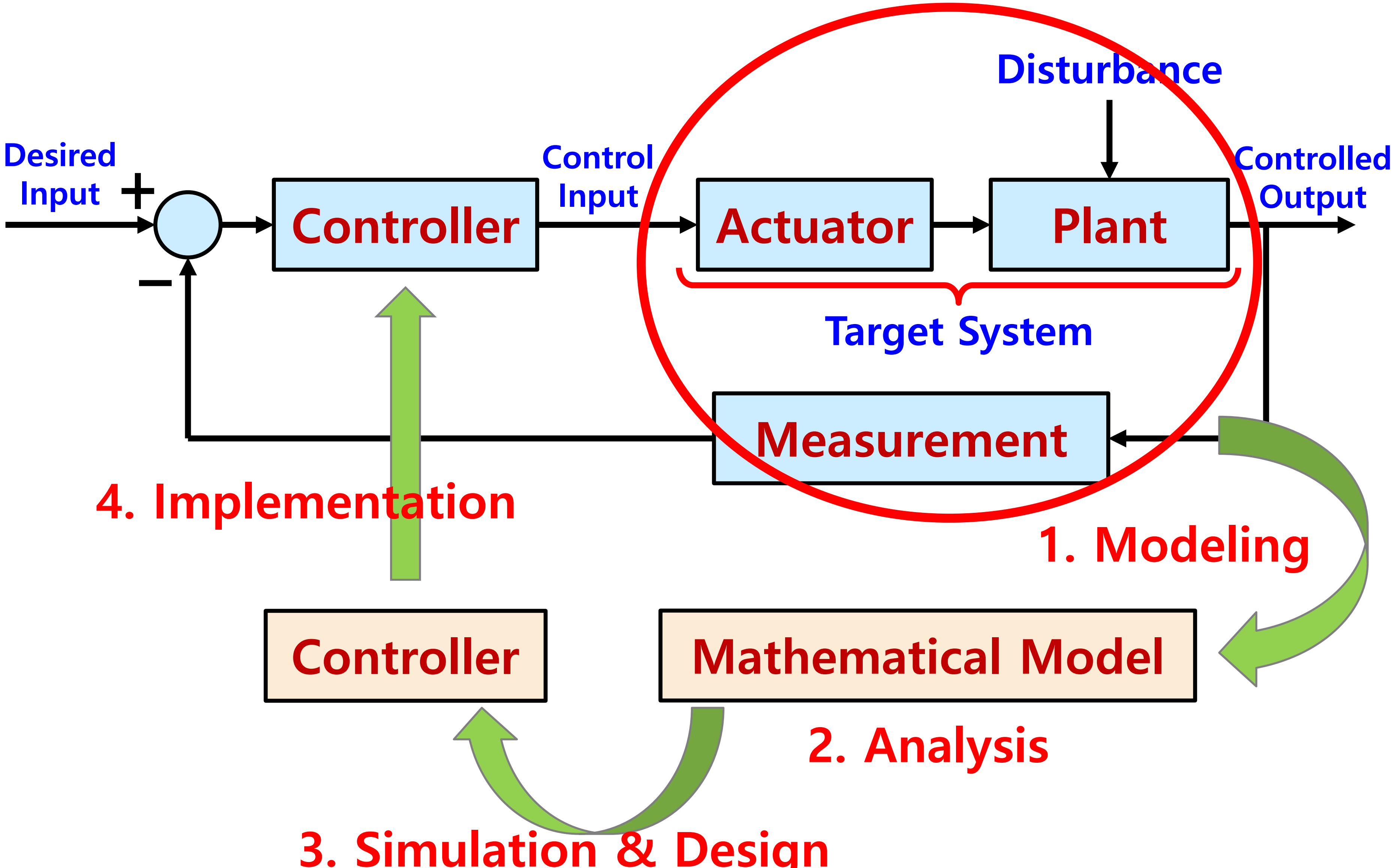
❖ Self-(Controlled)-Driving Car by BMW

https://www.youtube.com/watch?v=xsQvq4WlUYU

Course Objectives are

- **To Understand** about what the diverse automatic control systems are in the whole world.
- **To Model** dynamic systems in the diverse fields: Mechanical, Electrical, Biological and Chemical Systems.
- **To Design** the controller based on the system dynamic models.
- **To Analyze** control system response and stability.
- **To Test** the controller by designed through simulations.

Course Objectives are (cont'd)



Open-loop Control

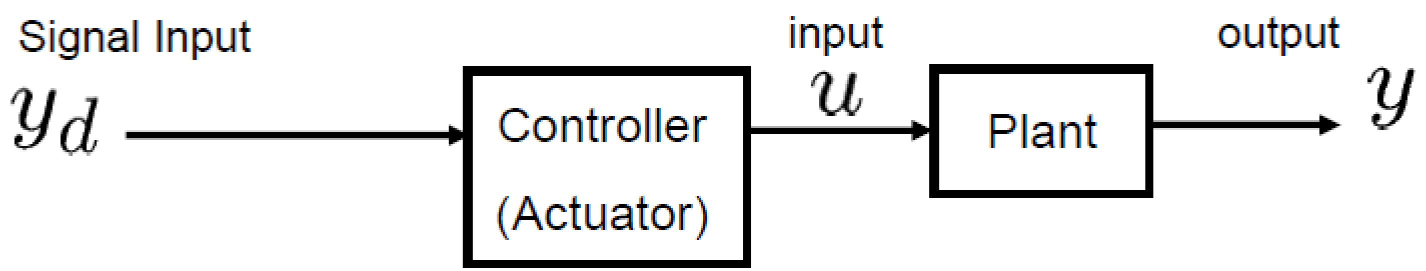
vs.

Closed-loop Control

Control Loop (1): Open-Loop Control

❖ Open-Loop Control System

- Toaster, microwave oven, shooting a basketball



- Calibration is the key !!
- Can be sensitive to **disturbances** !!

Example: Toaster

❖ A toaster toasts bread, by setting timer.

❖ Objective: make bread golden browned and crisp.

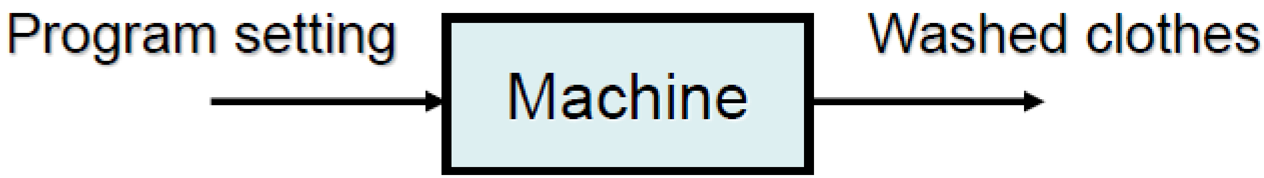
❖ A toaster does not measure the color of bread during the toasting process.

❖ For a fixed setting, in winter, the toast can be white and in summer, toast can be black (Calibration is needed !!)

❖ A toaster would be more expensive with sensors to measure the color and actuators to adjust the timer based on the measured color.

Example: Laundry Machine

❖ A laundry machine washes clothes, by setting a program.

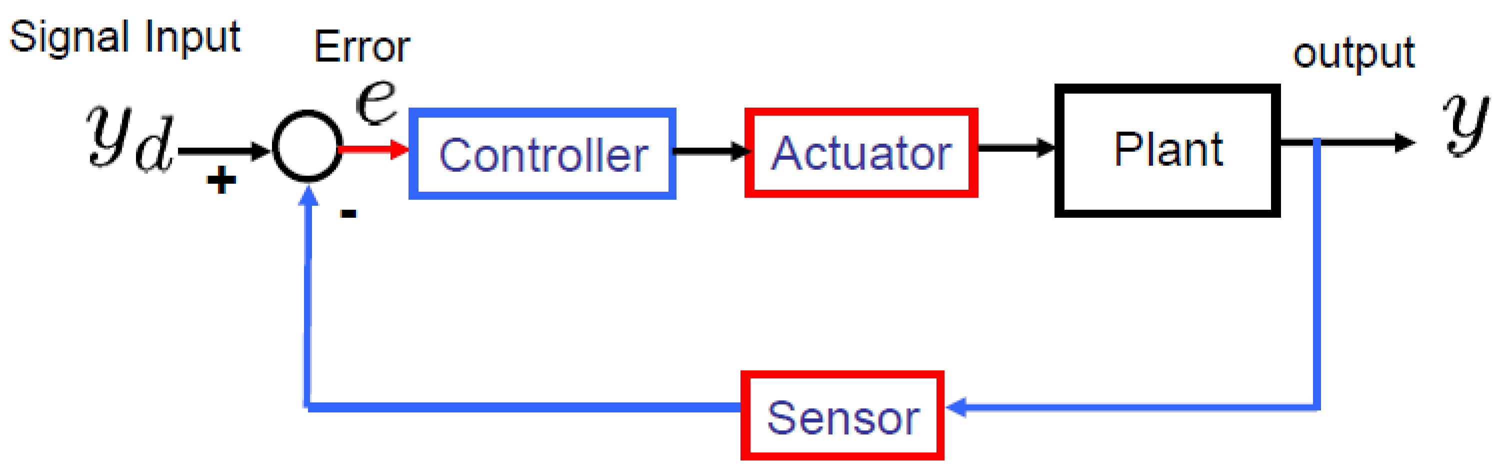


❖ A laundry machine does **not measure** how clean the clothes become.

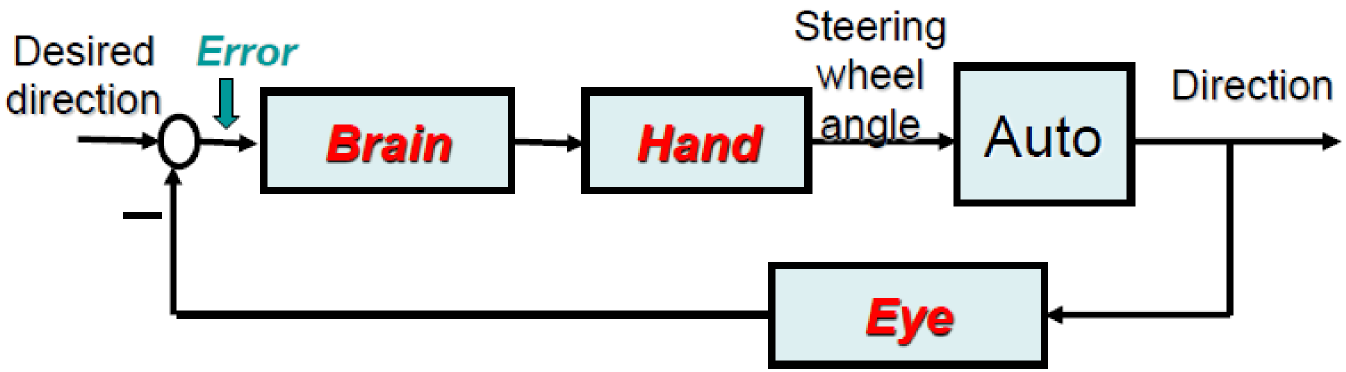
❖ Control **without measuring devices (sensors)** are called **open-loop control**.

Control Loop (2): Closed-Loop (Feedback) Control

- **Compare** actual behavior with desired behavior.
- Make **corrections** based on the error.
- Thus, the **sensor** and the **actuator** are key elements of a feedback loop.
- So, it require to design **control algorithm !!**

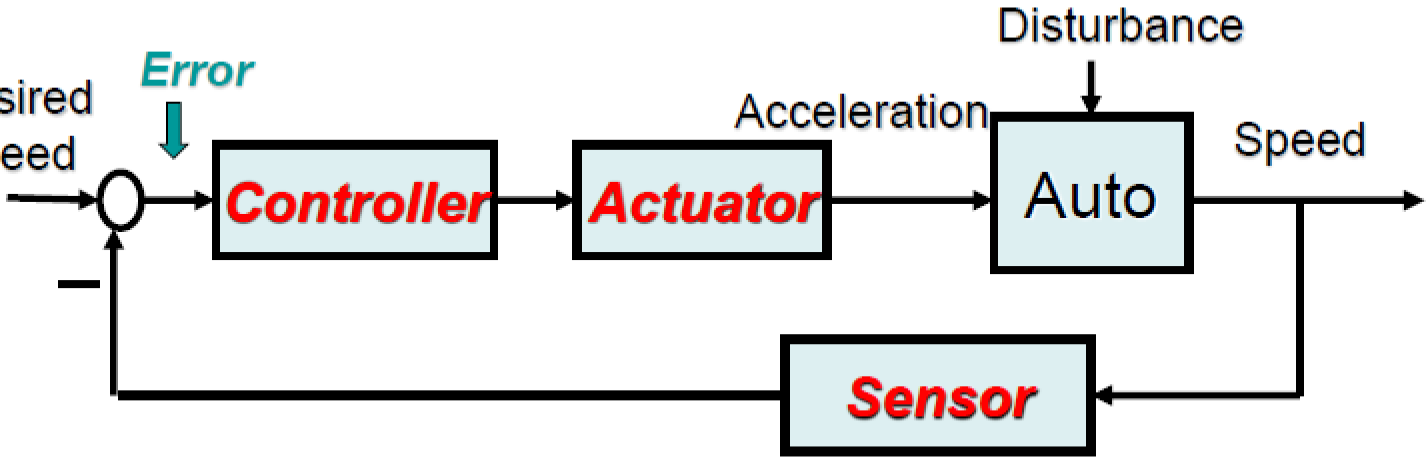


Ex: Automotive Direction Control (Manual)



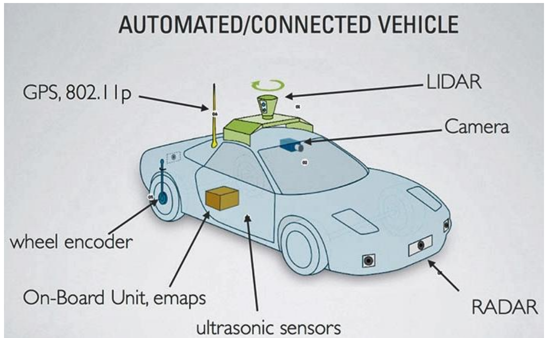
- ❖ Objective: to change the direction of the automobile.
- ❖ Manual closed-loop (**feedback**) control.
- ❖ Although the controlled system is "Automobile", the **input** and the **output** of the system can be different, depending on **control objectives** !!

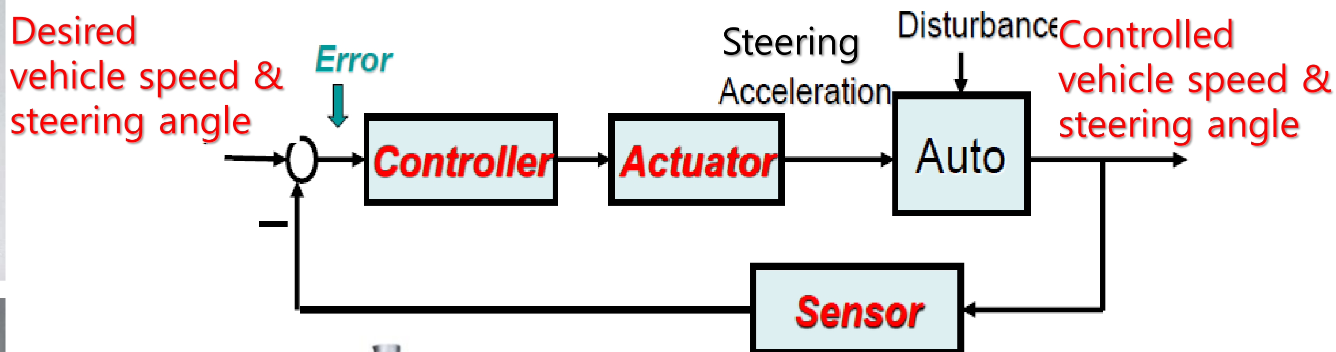
Ex: Automotive Cruise Control (Automatic)



- Objective: to **maintain the speed** of the automobile.
- Cruise control can be both manual and automatic.
- Note the similarity of the diagram above to the diagram in the previous slide !!

Ex: Fully Autonomous Vehicle Control



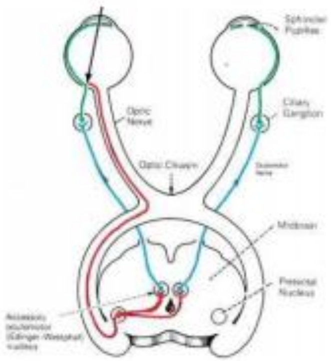


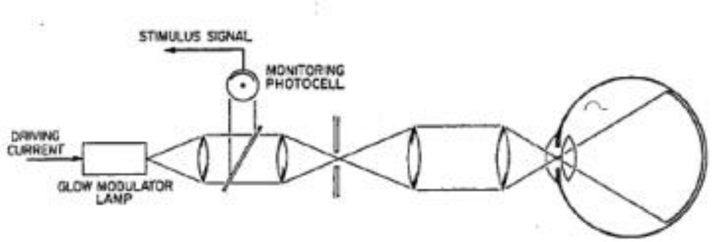
- Objective: to **maintain the vehicle speed and steering angle** of the automobile.
- Desired vehicle speed and steering angle should be determined by diverse sensors (LiDAR, Camera, GPS, radar and others) for self-driving.

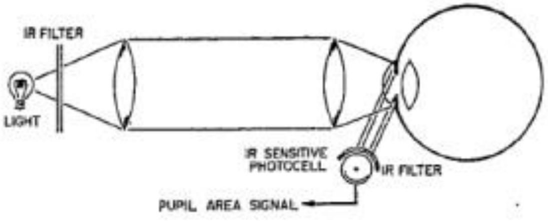
Other Important Control Systems:

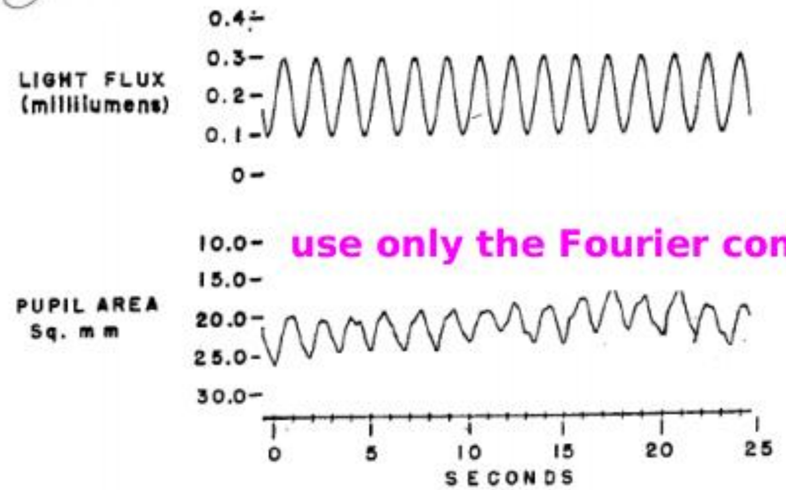
Biological & Chemical Systems

Biological Example #1: Physiological Systems







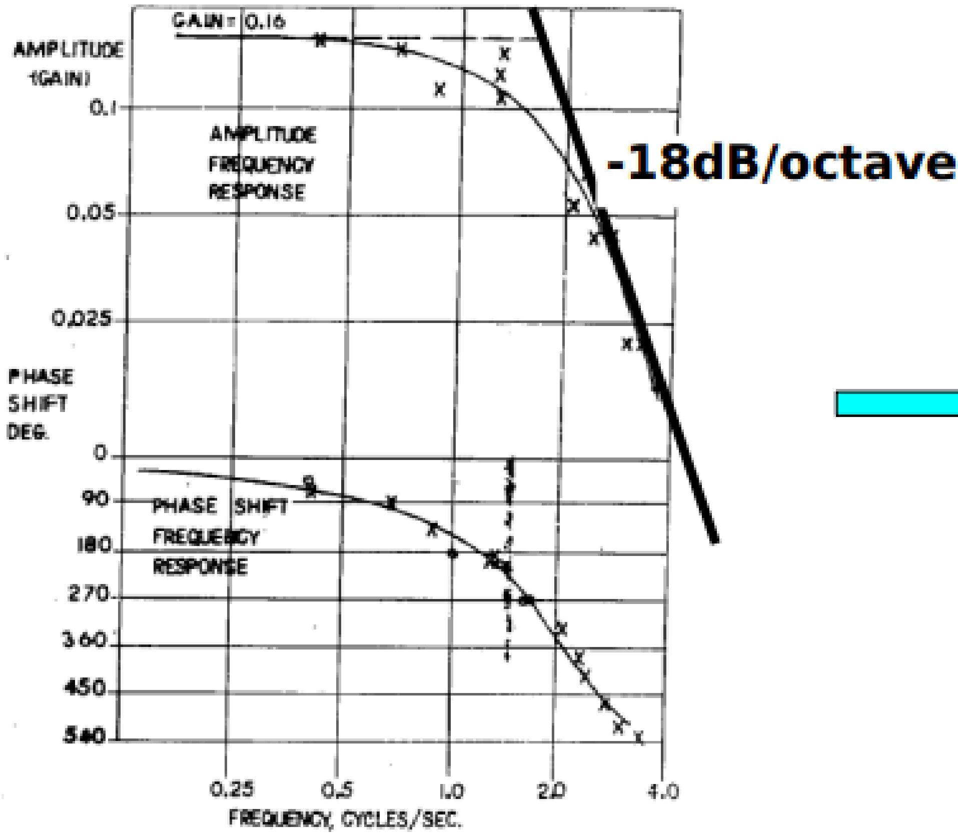


use only the Fourier component at the forcing frequency

Source: Lawrence Stark, Neurological Control Systems, Plenum Press, 1968

Biological Example #1: Physiological Systems

Bode Plots for the pupillary reflex (동공 반응 정도)



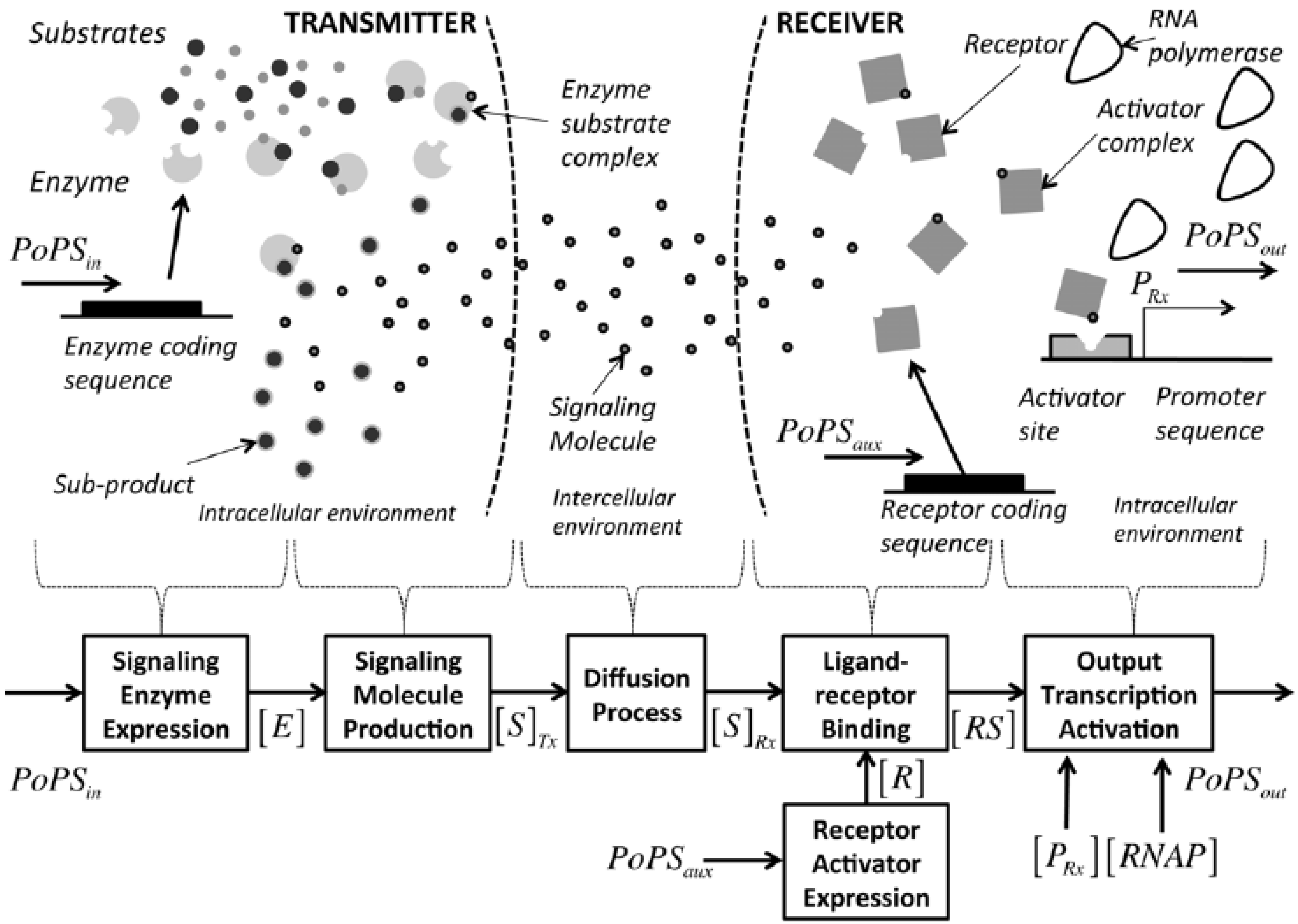
time delay

$$\frac{0.16e^{-0.18s}}{(1+0.1s)^3}$$

transfer function

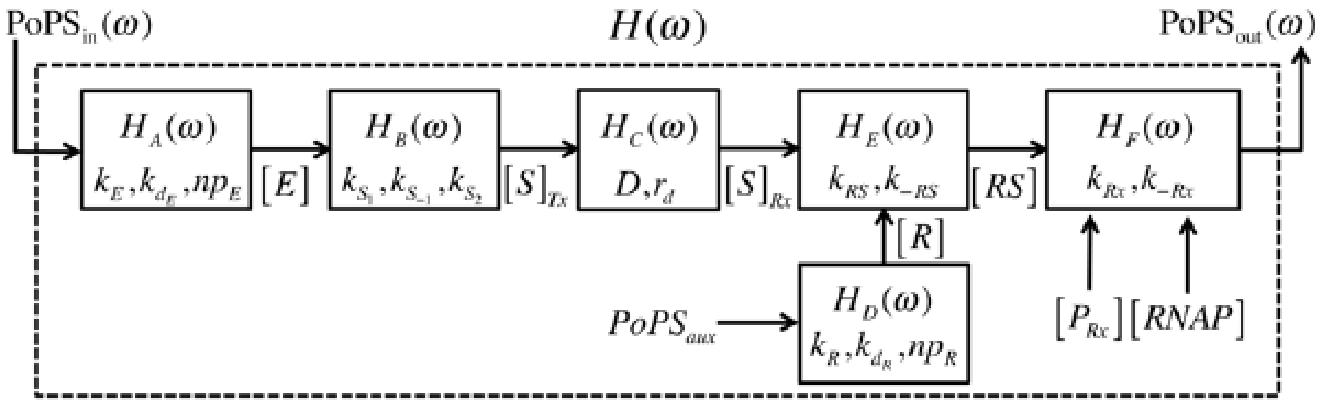
Biological Example #2: Molecular Communications

Source: M. Pierobon / Nano Communication Networks 5 (2014) 25–34.



Source: M. Pierobon / Nano Communication Networks 5 (2014) 25–34.

Biological Example #2: Molecular Communications



Transfer functions for each molecular communication process

$$H_A(\omega) = \frac{np_E k_E}{j\omega + k_{d_E}},$$

$$H_B(\omega) = \frac{k_{S_1}}{\omega\{j(k_{S_{-1}} + k_{S_2}) - \omega\}},$$

.....

$$H_F(\omega) = \frac{k_{Rx}}{j\omega + k_{-Rx}},$$

$$H(\omega) = \frac{np_E k_E}{j\omega + k_{d_E}} \frac{k_{S_1}[S_0]}{\omega\{j(k_{S_{-1}} + k_{S_2}) - \omega\}} \times j\omega \frac{e^{-(1+j)\sqrt{\frac{\omega}{2D}} r_{Rx}}}{\pi D r_{Rx}} \cdot \frac{np_R k_R}{k_{d_R}} PoPS_{aux} \frac{k_{RS}}{j\omega + k_{-RS}} \cdot \frac{k_{Rx}}{j\omega + k_{-Rx}} [P_{Rx}][RNAP],$$

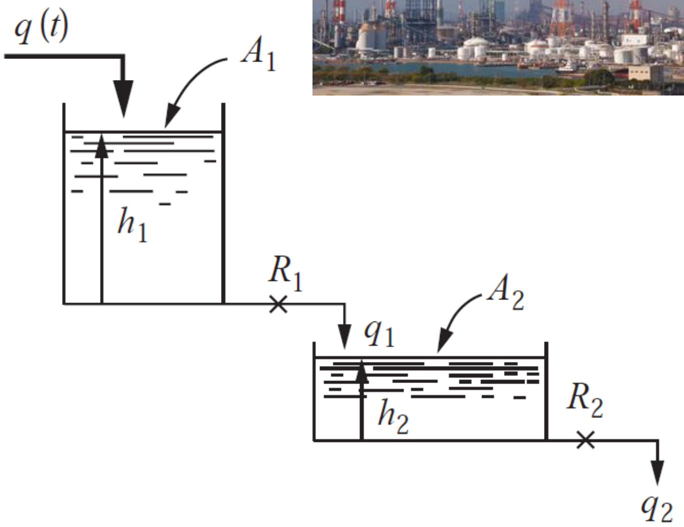
Chemical Example #1: Process Control

Multi Tanks in Series of Chemical Process

$$q - q_1 = A_1 \frac{dh_1}{dt}$$

$$q_1 - q_2 = A_2 \frac{dh_2}{dt}$$

Flow Resistance Constant



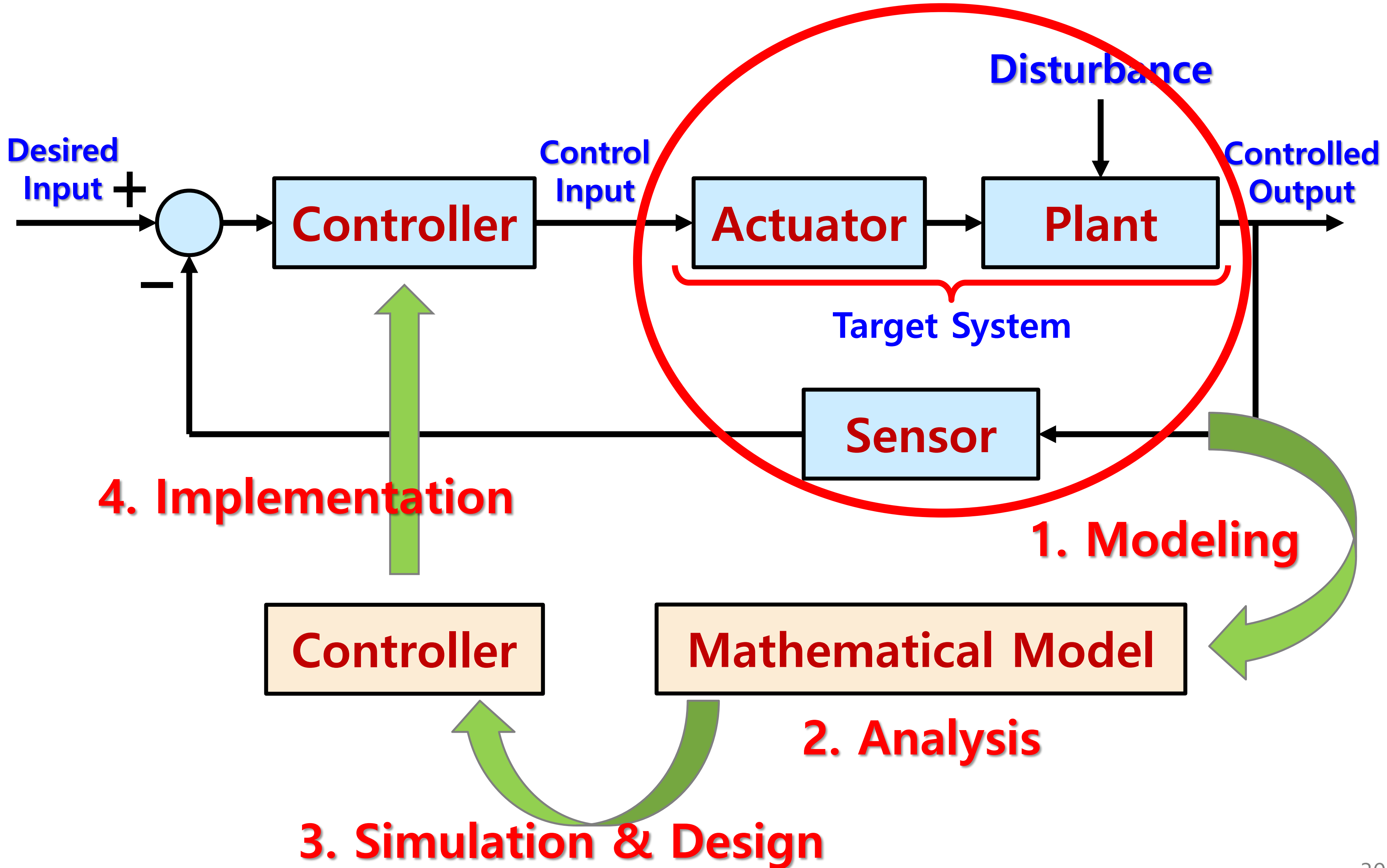
Where, $q_1 = \frac{h_1}{R_1} \quad q_2 = \frac{h_2}{R_2}$

$\mathcal{L}$

$$\frac{Q_1(s)}{Q(s)} = \frac{1}{\tau_1 s + 1} \times \frac{H_2(s)}{Q_1(s)} = \frac{R_2}{\tau_2 s + 1} \Rightarrow \boxed{\frac{H_2(s)}{Q(s)} = \frac{1}{\tau_1 s + 1}\frac{R_2}{\tau_2 s + 1}}$$

Where, $\tau_1 = R_1 A_1. \quad \tau_2 = R_2 A_2.$

Summary: goals of this course



Summary

❖ **Summary:**
- What is the Control?
- Examples of control systems
- Concept of open-loop & closed-loop (feedback) control system