Control Systems

ECE 486: Course Introduction

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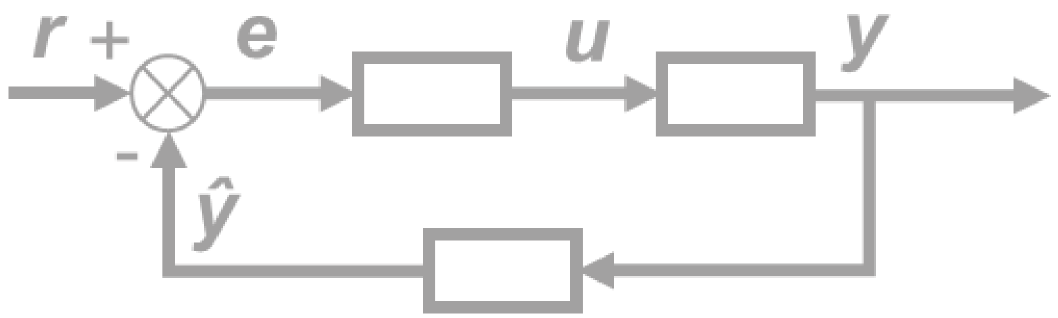
Course Description:
ECE 486 Control Systems

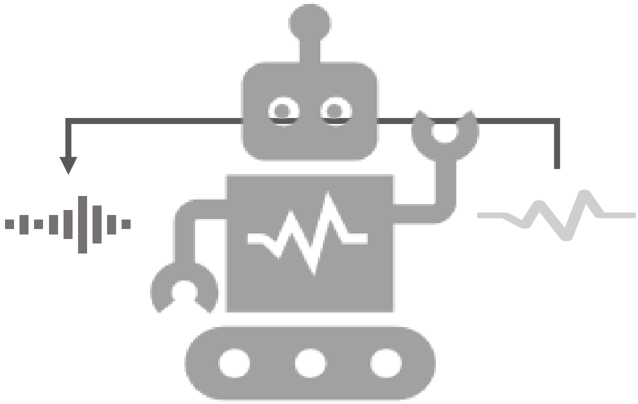
- Analysis & design of control systems
- Emphasizing modeling, state variable representation, computer solutions, modern design principles, and laboratory techniques (Undergrads).
- Covering the following topics:
    - Modeling and dynamic response
    - Root locus design method
    - Frequency response design methods
    - State-space design methods

Control Systems



Course Objective: ECE 486 Control Systems

- Acquire a design-oriented approach
  - develop the ability and interest in continued study of advanced topics.
- Familiarizes with basic concepts providing a foundation for further development beyond the fundamentals of the subject.
- Master important design methodologies through hands-on computer-based analysis practical lab session (undergrad)



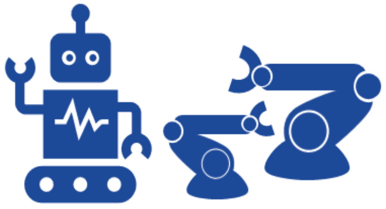
Self-Introduction: Teaching

- Dynamics of Mechanical Systems *ME 340*
- Control Systems *ECE 486*
- Signal Processing *ME360*
- Intro. to Robotics *ECE 470/ ME 445*

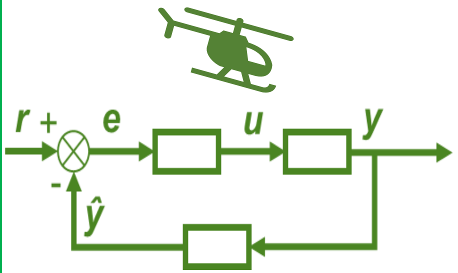
Dynamics

Signal Processing

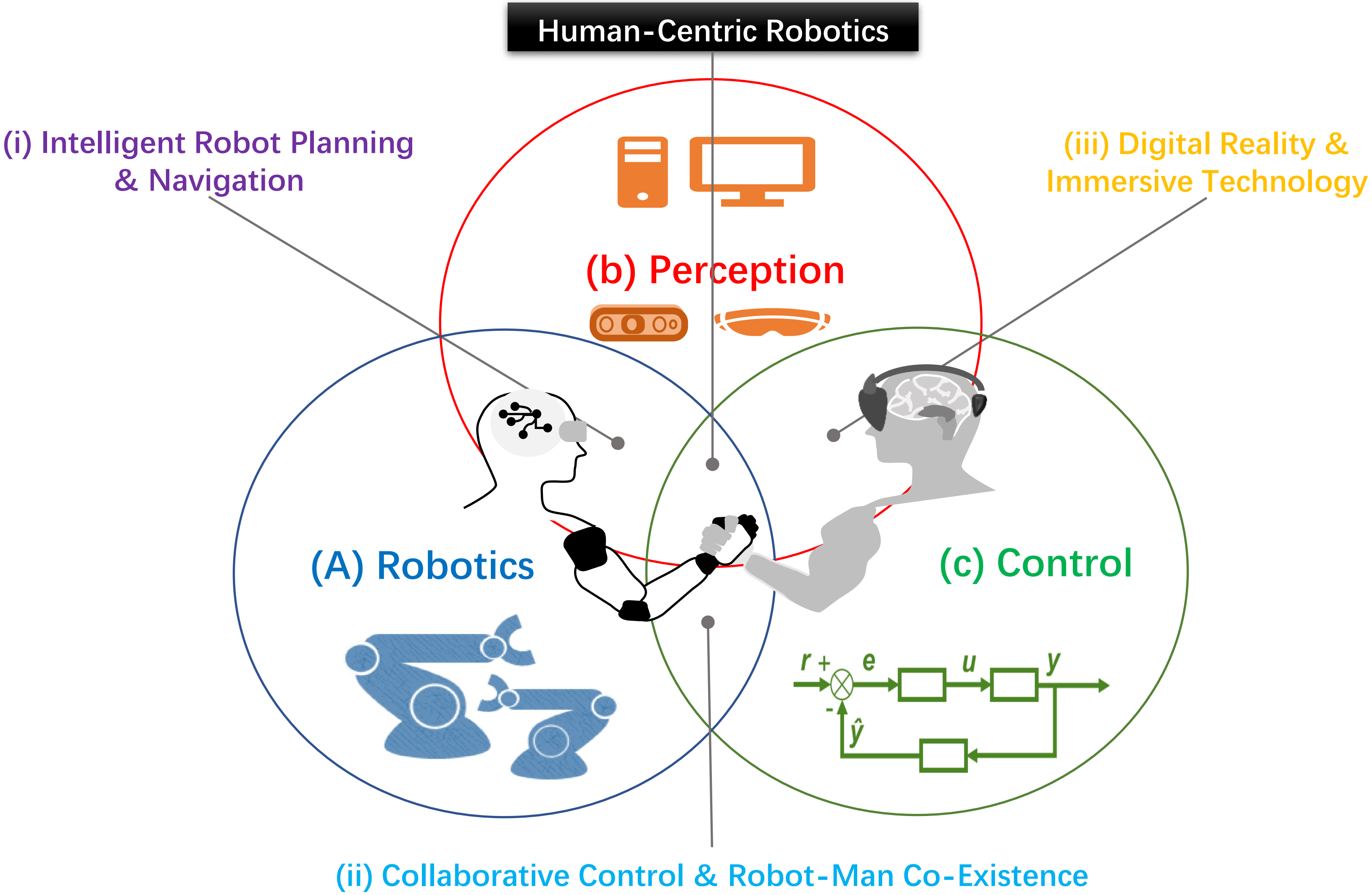
Robotics



Controls Systems



Self-Introduction: Research



Teaching Team @ ZJUI

Instructor

Liangjing Yang
Assistant Prof., ZJUI
(liangjingyang@intl.zju.edu.cn)

Teaching Assistants

Tiexing Wang
PhD. Student

Vision-Based Micromanipulator Control

Yunze Shi
PhD. Student

Human-Robot Collaborative Control

Tanhong Pu
M.Sc. Student

Mixed-Reality Based Micromanipulator

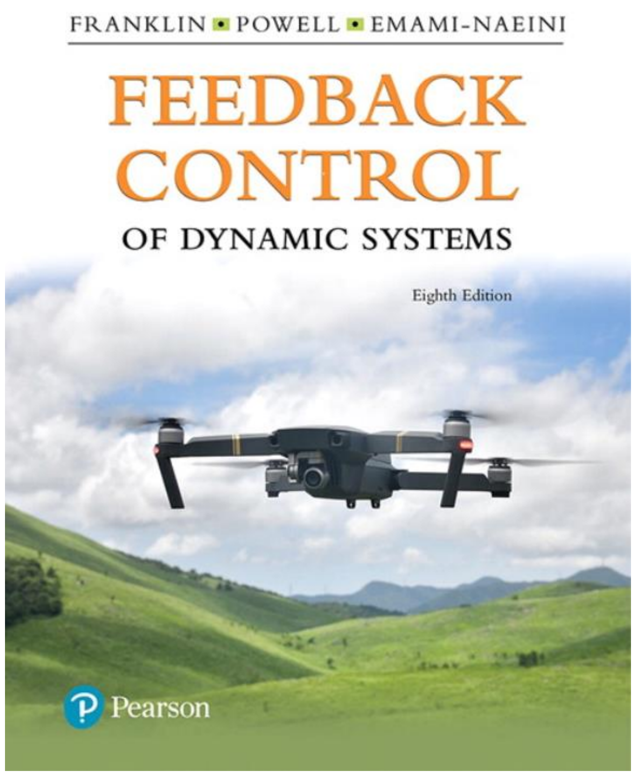
Yizhou Huang
M.Sc. Student

Dynamic Compliance Control

Senior Year Lab TAs:
Tianle Weng, Liu Pengzhao, ZJUI

Admin. Matters

- **Prerequisite:** ECE 210 (Analog Signal Processing); Basic knowledge of complex numbers and linear algebra is a plus.
- **Reference Textbook:** Franklin, Powell, and Emami-Naeini, Feedback Control of Dynamic Systems, Prentice Hall.
- **Consultation:** Tue 0930-1130; Wed 1400-1600 @ E205 Instructional Control Lab, tentatively. (Feel free to arrange with me)
- **Grading Policy:** Class Participation- 5%; Homework- 20%; Lab- 30%; Midterm Exams- 20%; Final Exam- 25%



Admin. Matters

Control Systems Project (Graduates)

You will have a choice of doing **ONE** of the following options:

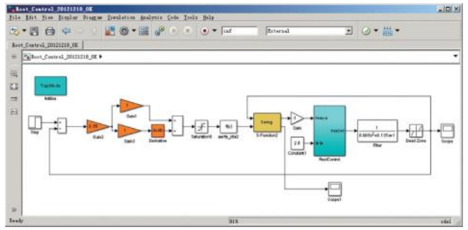
A. A literature review on Control Systems relevant to your field of interest
  - historical development, existing state-of-the-art technology and an analysis of the development prospect
  - draw relevance towards your field of interest
  - apply understanding in control systems towards your area(s) of expertise.

B. A simulation-based project related to control systems
  - control theory for **engineering application** or
  - **scientific methodology** in analytical studies related to control systems.

C. A prototype development project related to control systems
  - control theory for **engineering application** or
  - **scientific methodology** in analytical studies related to control systems

Lab Sessions (Undergrads)

Lab 0: Matlab Simulation
Lab 1: Analog simulation & circuit prototyping
Lab 2: Digital simulation
Lab 3: Digital simulation of closed loop-system
Lab 4: DC motor & PID Control
Lab 5: Control Design using Frequency Response Method
Lab 6: Control Design using State-Space Model



ECE 486 Control Systems

Lecture 01: Introduction to Feedback Control

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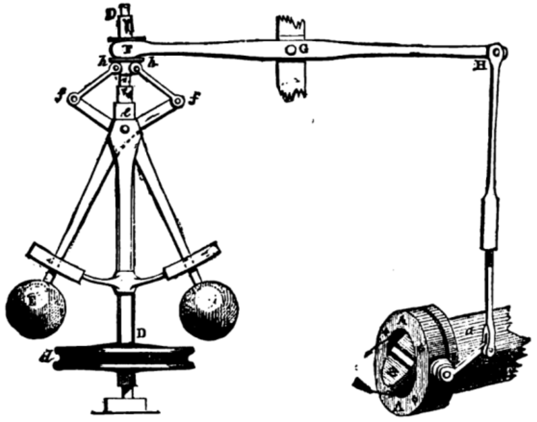
Lecture Overview

- Introduce the concept of control systems
- Understand feedback control
- Appreciate feedback control system as a mean of achieving more reliable outcome
- Discuss of the past, present and prospective development in the field of control

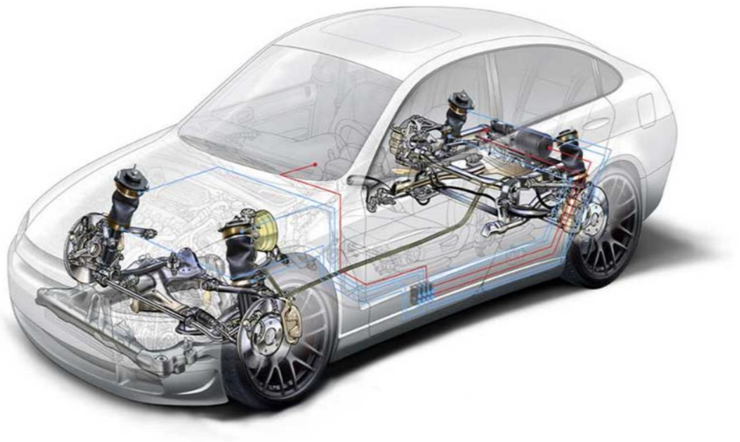
Concept of Control Systems

- A **control system** is designed to achieve a targeted **output** by generating the appropriate **inputs** in a **dynamical environment** (within specified **performance criteria**)

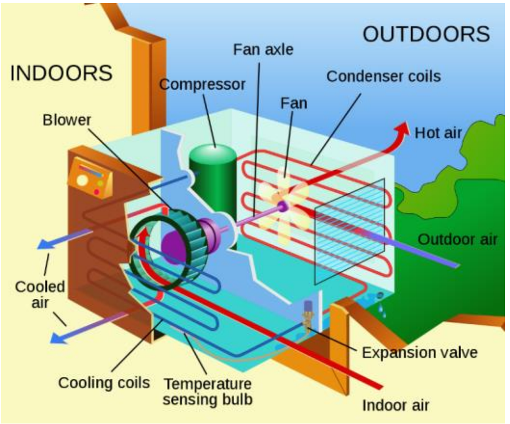
Examples of Control Systems



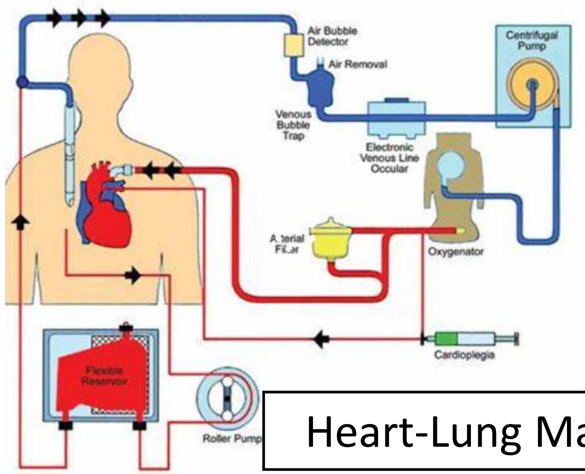
Centrifugal Governor



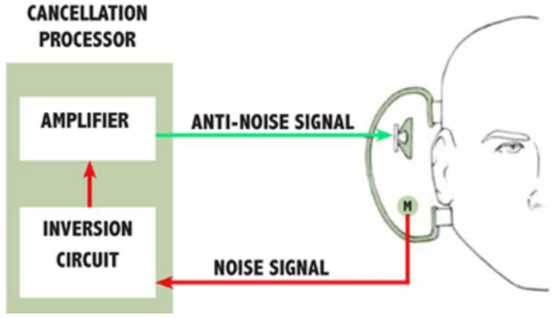
Active Suspension



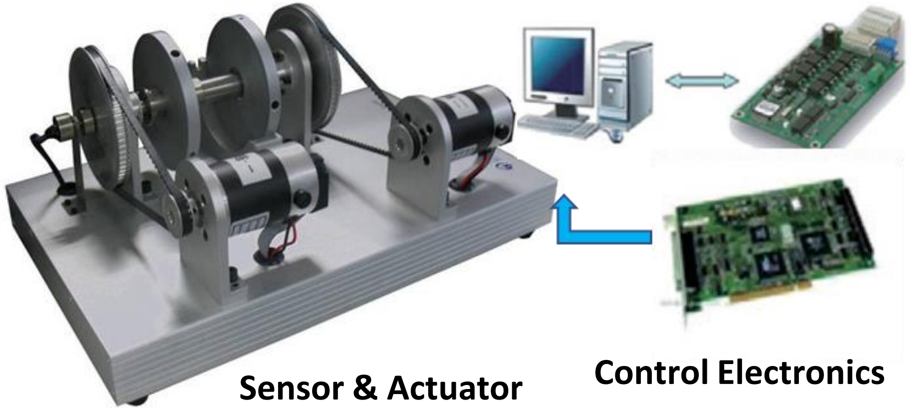
Air Conditioning System



Heart-Lung Machine

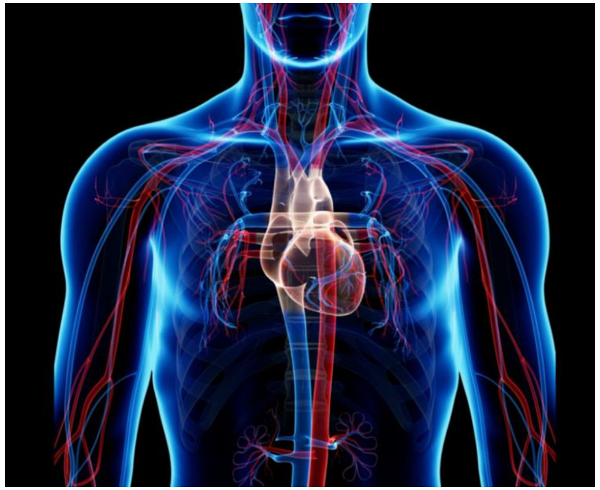


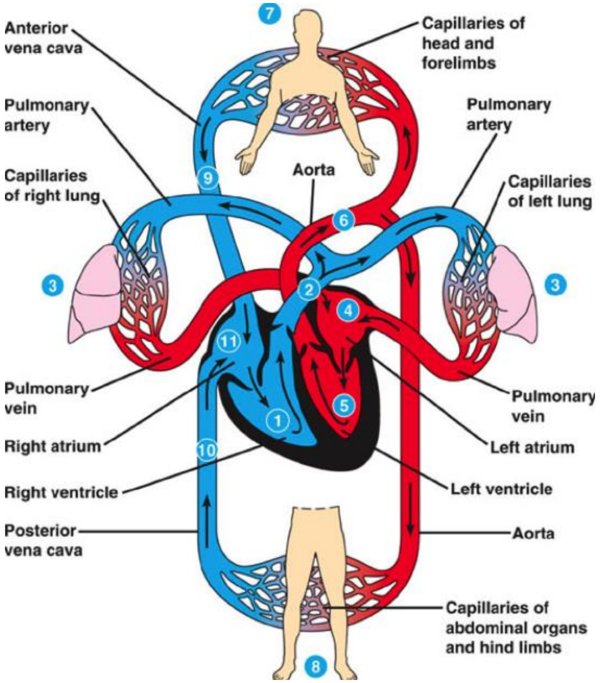
Active Noise Cancellation

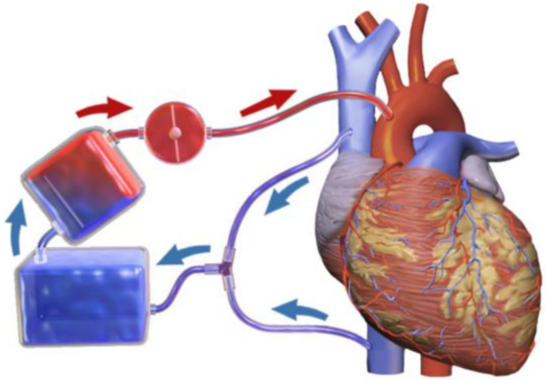


Motor Control

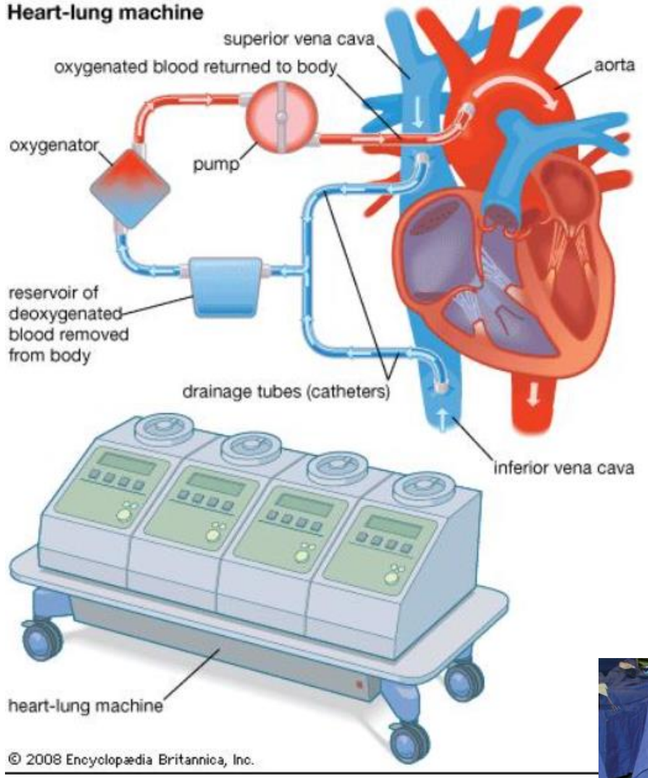
A Magnificent Dynamic System: Cardiopulmonary System

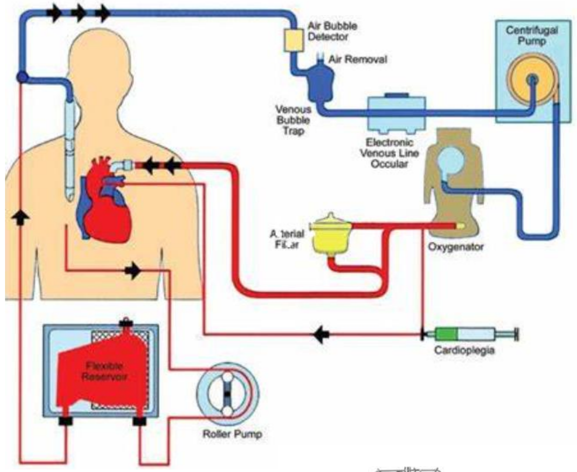


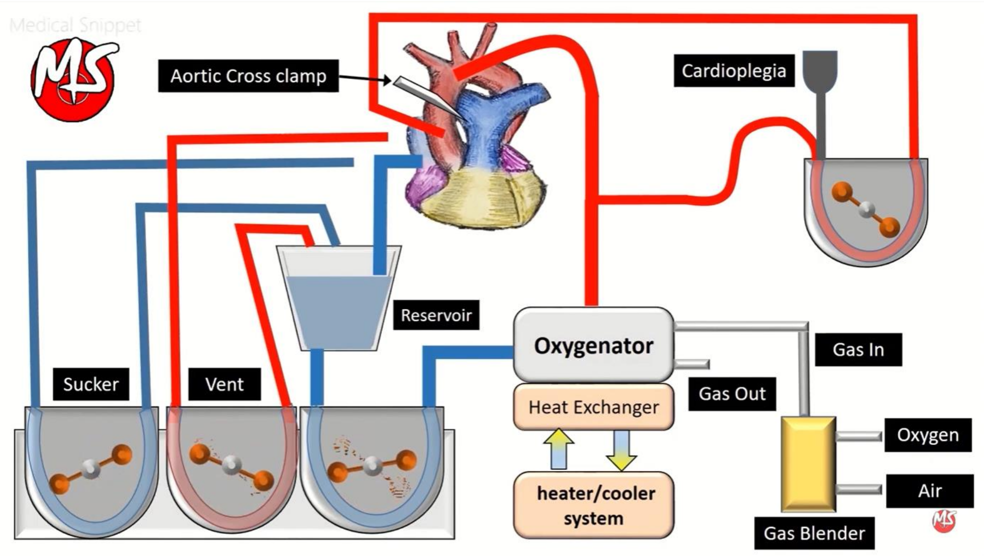




Engineering the Cardiopulmonary System



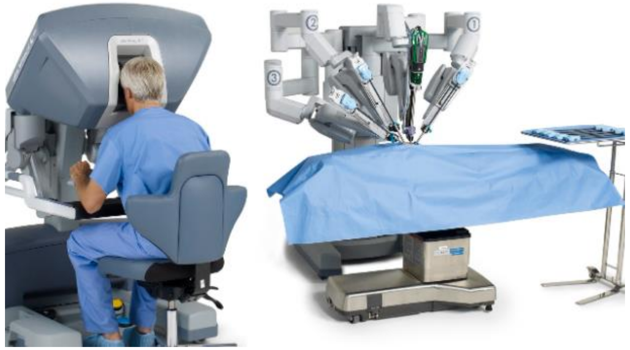
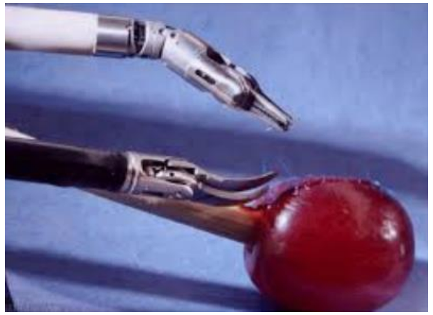




Reason for Control Systems

- Power Amplification
- Motion Scaling
- Remote Operation
- Ease of Input
- Compensation of Disturbance



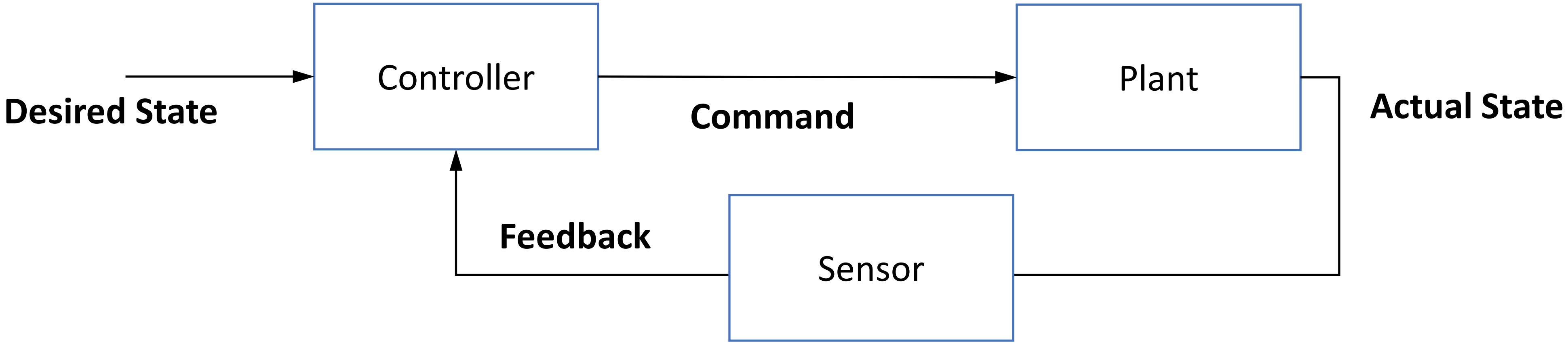



Control

Open-loop

Through preestablished model, generate the command that will achieve the desired state.

Closed-loop



Through sensors, we are able to **feedback** the measurement to produce the command that will minimize the error between desired and actual targeted profile.

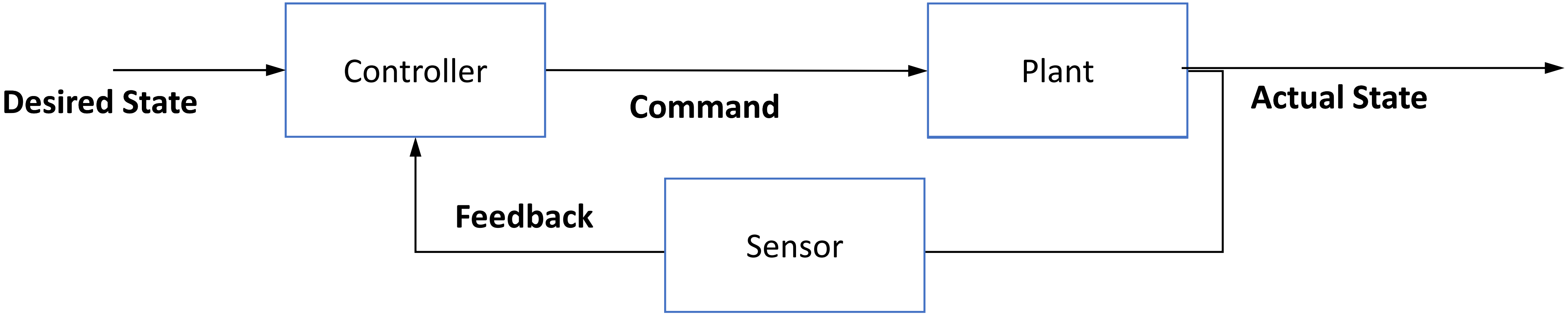
Control

Open-loop

Through preestablished model, generate the command that will achieve the desired state. This is known as a **open-loop system**.

Control

Closed-loop



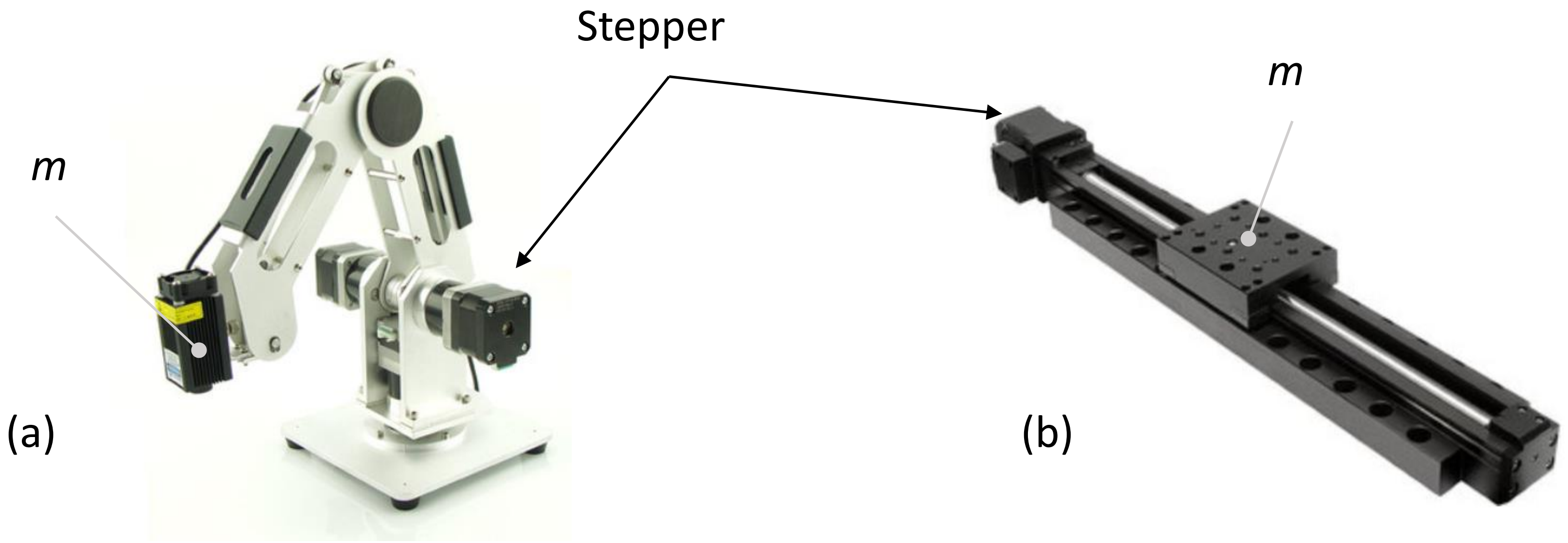
Through sensors, we are able to **feedback** the measurement to produce the command that will minimize the error between desired and actual targeted profile. This is known as a **closed-loop system**.

Open vs. Closed loop

	Open	Closed
Cost	Economical 🙂	Expensive 🙁
Design	Simple 🙂	Complex 🙁
Accuracy	Erroneous 🙁	Accurate 🙂
Reliability	Unreliable 🙁	Reliable 🙂

Open vs. Closed loop

- Imagine you are controlling the position of the mass, *m* using a stepper motor by inputting the number of steps.
- Which mechanism (a) or (b) will open loop control be more suitable for? Discuss.



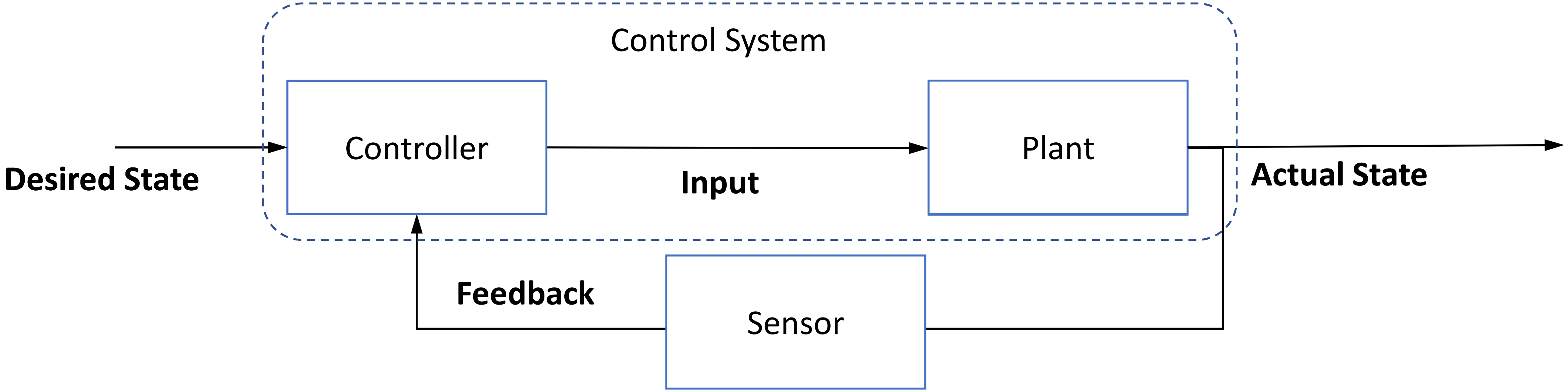
Open vs. Closed loop

- Due to the low transmission ratio of a translational stage in (b), external disturbance has insignificant influence to the position of *m*
- Hence, open loop control is adequate for (b) to map to a desirable output reliably
- The opposite is true.
- Hence, closed-loop is required for (a) <u>to ensure reliability and accuracy</u>

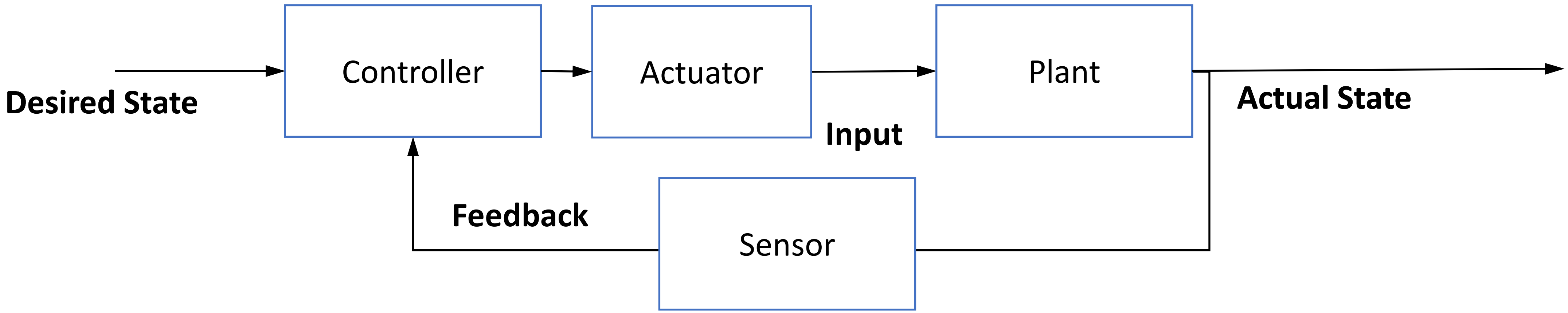
Control Systems

- A **control system** is designed to achieve a targeted **output** by generating the appropriate **inputs** in a **dynamical environment** (within specified **performance criteria**)

Feedback Control

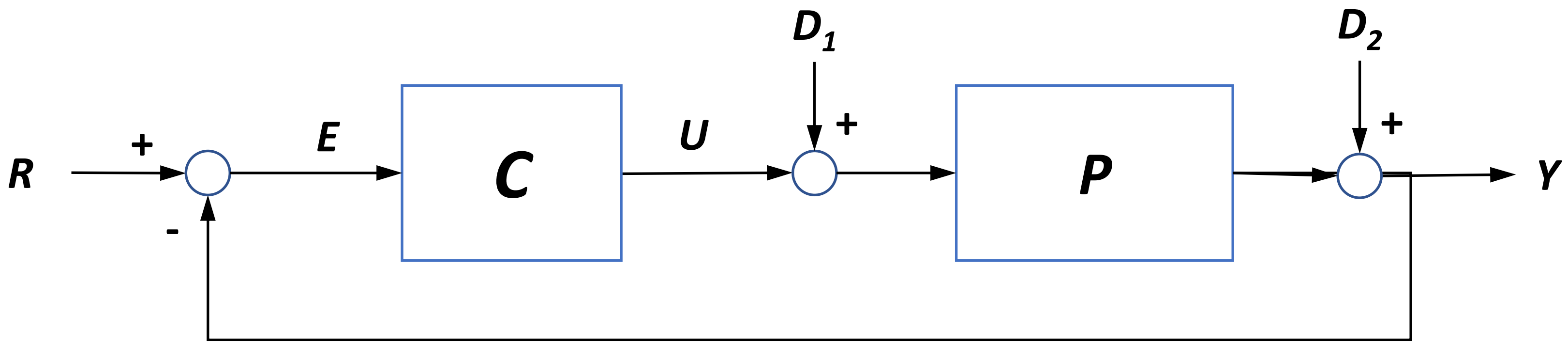


Terminology



- **Plant** is the system being controlled
- **Sensors** measure the quantity that is subject to control
- **Actuators** act on the plant
- **Controller** processes the sensor signals and drives the actuators
- **Control law** is the rule for mapping sensor signals to actuator signals

Feedback Control



Systems
C : Controller
P : Plant

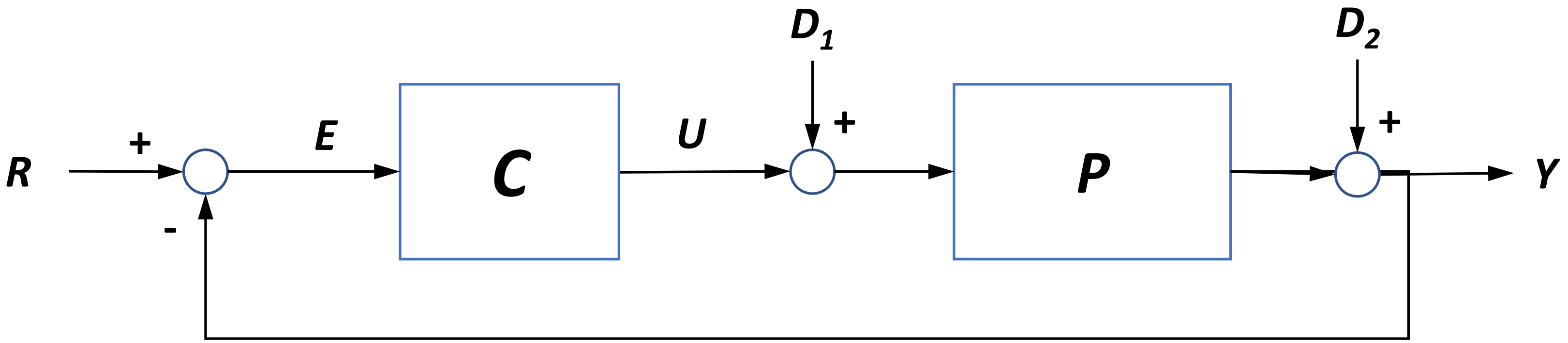
R : Reference
E : Error

Variables
U: Input
Y: Output

D_1: Disturbance 1
D_2: Disturbance 2

Relations
$Y=D_2+P(U+D_1)$
$U=CE$;
$E=R-Y$

Feedback Control



Relations

$Y=D_2+P(U+D_1)$; $U=CE$; $E=R-Y$

Expressing Y in terms of R, D_2, D_1

$Y = D_2+P(CE+D_1)$

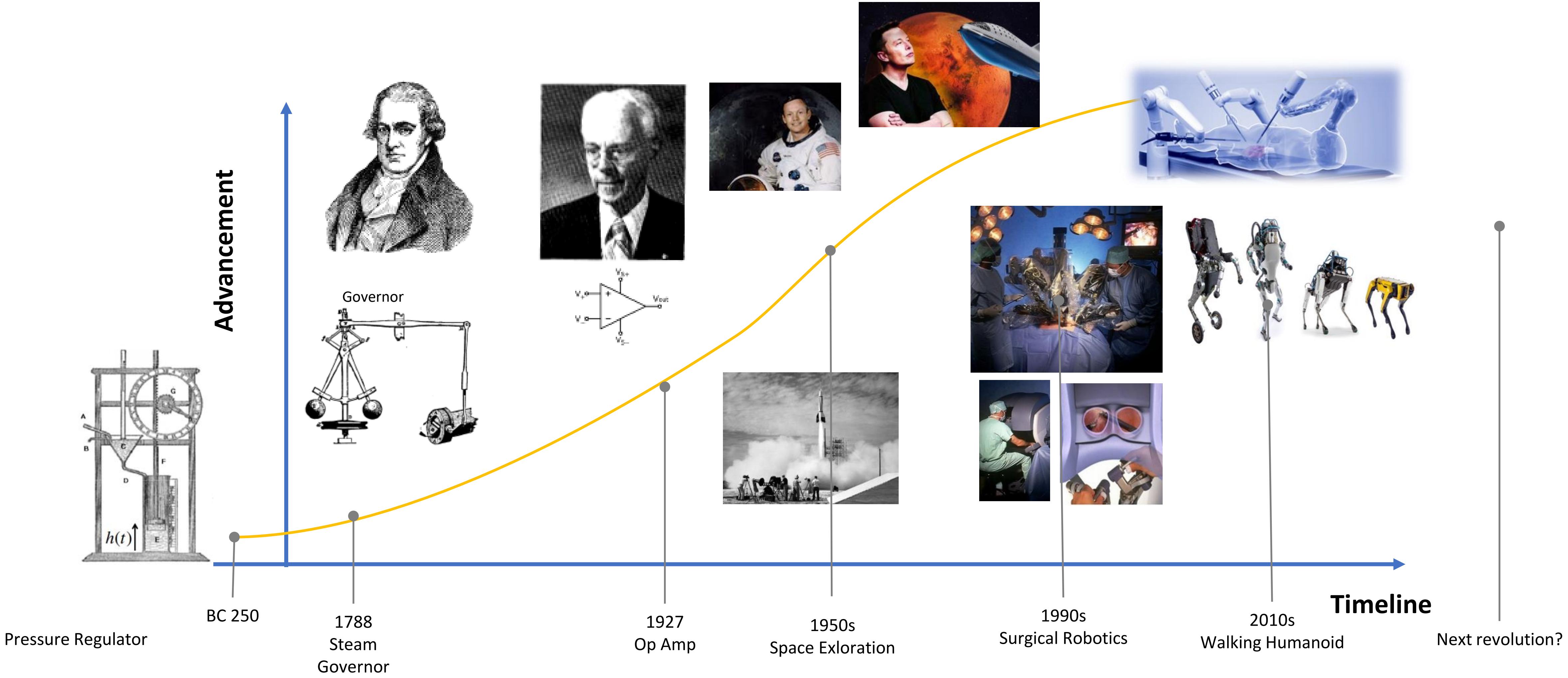
$=D_2+P(C(R-Y)+D_1)$

$=D_2+PCR-PCY+PD_1$

$$Y = \frac{PC}{1+PC}R + \frac{P}{1+PC}D_1 + \frac{1}{1+PC}D_2$$

What happen when C keeps getting larger?

Past, Present, Prospect of Control



Next Lecture

- State-Space Models of Systems

- Linearization

$$
\begin{aligned}
\dot{x} &= Ax + Bu \\
y &= Cx
\end{aligned}
$$