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ELEC 341: Systems and Control

Lecture 1

Introduction
to dynamic systems and control

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Remark before starting …

- All the lecture slides will be posted on Canvas.
- You may want to write down additional information that I present in the lecture on the slides.

Today's outline

- Practical information
- Introduction to the course

Instructor and TAs

- Instructor:
  - Siamak Najarian, Ph.D., P.Eng., Professor of Biomedical Engineering (retired)
    - **Email:** siamak.najarian@ubc.ca or siamakn@ece.ubc.ca
    - **Office:** MacLeod Building 451
    - **Office hours:** Tuesdays and Thursdays from 1:00 pm to 2:30 pm.
    - **Research interest:** Biomedical Engineering
- TAs:
  - Mr. Su Wang; suwang@msl.ubc.ca and Mr. Mohammad Najjarzadegan; najjarzadegan@ece.ubc.ca
- Note:
  - For any assignment-related issues, please contact Mr. Su Wang and Mr. Mohammad Najjarzadegan.
  - For assignments group formation (i.e., member names), please only contact Mr. Su Wang; suwang@msl.ubc.ca .

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Course information

- Canvas (Check regularly!)
  - All information on this course, including lecture slides, assignments, and announcements, will be posted on Canvas.
- **Required course materials:** Course lecture notes
- **Important Note:**
  - ✓ Please download and go through the document entitled "Syllabus and Course Outline for ELEC 341" on Canvas. It contains important information about the course.

Main components of the course

- **Lectures:**
  - **Time and Building:** From 10:00 am to 12:pm; Mon Tue Wed Thu (MacLeod 228)
- **Group assignments:**
  - They will be posted on Canvas and your solutions should also be uploaded by you on Canvas (i.e., paperless). Each group will have 6 members.
- **Exams:**
  - Midterm
  - Final
- **Quizzes:**
  - There will be 2 quizzes and their dates have already been announced.

Course grading

- **Midterm and final exams:**
  - Midterm carries a weight of 35% and **final** a weight of **40%**.
  - Closed book/notes. One page letter-size hand-written crib-sheet (both sides) is allowed.
  - Regular scientific calculators are allowed (no graphing calculators).
- **Group assignments:**
  - They will be posted on Canvas and your solutions should be uploaded before the due dates. Total weight of **assignments** is **15%**.
- **Quizzes:**
  - Closed book/notes.
  - Multiple choice questions.
  - **Quizzes** will carry a total weight of **10%** (5% each).

Group Assignments	15%
Quizzes (2 x 5% each)	10%
Midterm Exam	35%
Final Exam	40%
Total	**100%**

Tips to succeed in this course

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- Come to the lectures as many times as you can.
- Bring lecture slides (print-out or electronically) to the lecture.
- Solve assignments problems and lecture notes examples.
- Keep pace with lectures by:
  - Reading the slides.
  - Solving assignments problems.

Outline

- Practical information
- Introduction to the course
  - Systems and control
  - Open-loop system and closed-loop system
  - Goal of the course

What is "Control"?

- Make some object behave as we desire.
- In control engineering, the controlled object is called ***system***, or ***plant***, or ***process***.
- Imagine "control" around you!
  - Room temperature control
  - Car/bicycle driving
  - Voice volume control
  - Balance of bank account
  - "Control" (move) the position of the pointer
  - etc.

What is “Automatic Control”?

- Not manual!
- Why do we need automatic control?
  - Convenient (e.g., room temperature control, laundry machine)
  - Dangerous (e.g., hot/cold places, space, bomb removal)
  - Impossible for human (e.g., nanometer scale precision positioning, work inside the small space that human cannot enter, huge antennas control, elevator)
  - Delicate and sensitive environment (smart surgical tools operating inside human body)
  - It exists in nature (e.g., human body temperature control).
  - High efficiency (e.g., engine fuel-injection control)
- Many examples of automatic control around us

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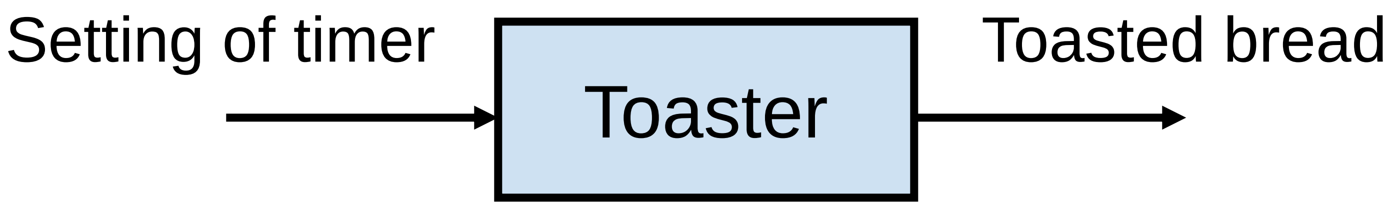
Example: Toaster

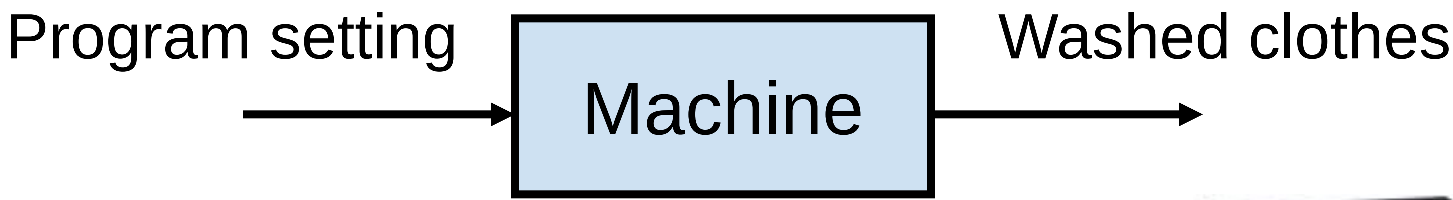
- A toaster toasts bread, by setting timer.



- A toaster does not measure the color of bread during the toasting process.
- What happens if your setting is wrong ...
- However, 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

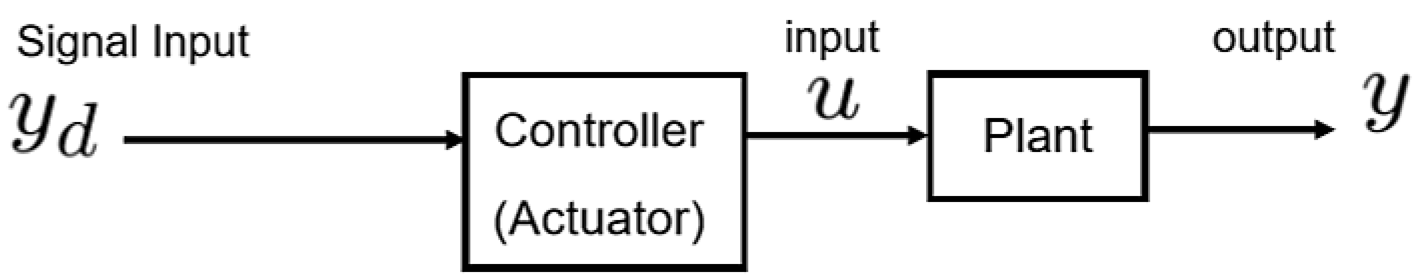
- A laundry machine washes clothes, by setting a program.



- A laundry machine does not measure how clean the clothes become.
- Control without measuring devices (sensors) is called ***open-loop control***.

Open-Loop Control

- Open-loop Control System
  - Toaster, microwave oven, shooting a basketball

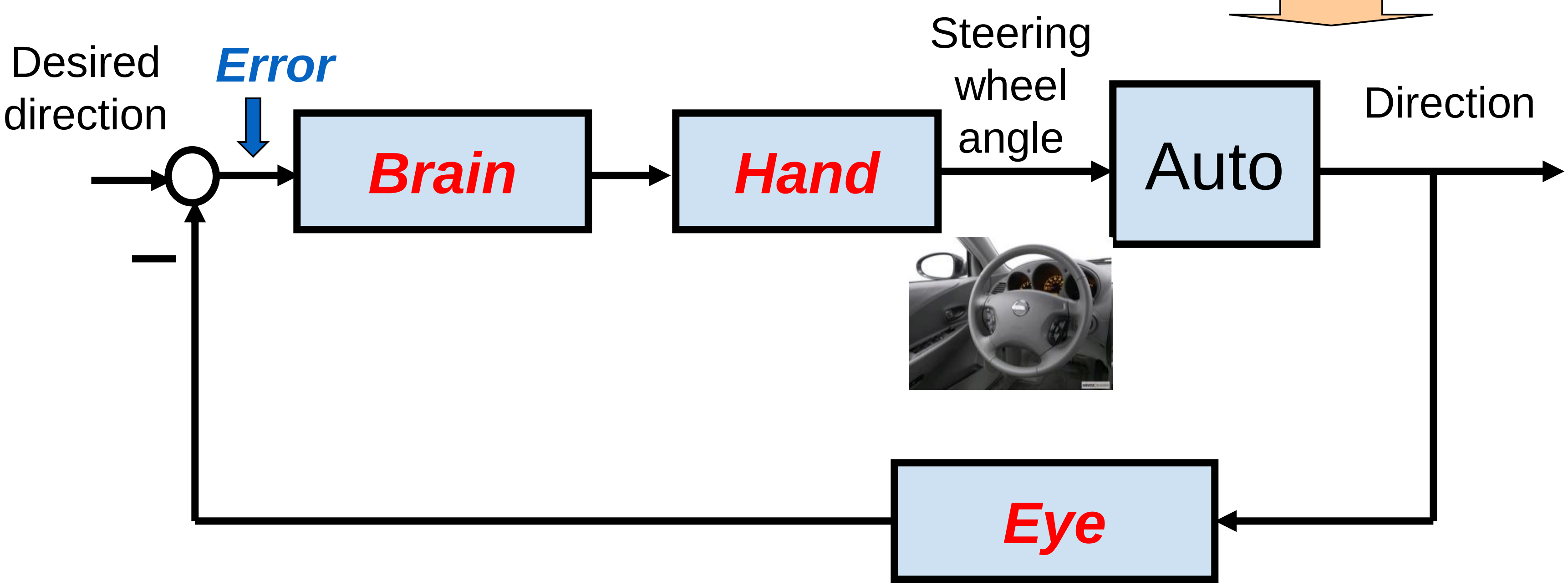


  - Calibration is the key!
  - Can be sensitive to disturbances

Ex: Automobile direction control

- Change the direction of the automobile.

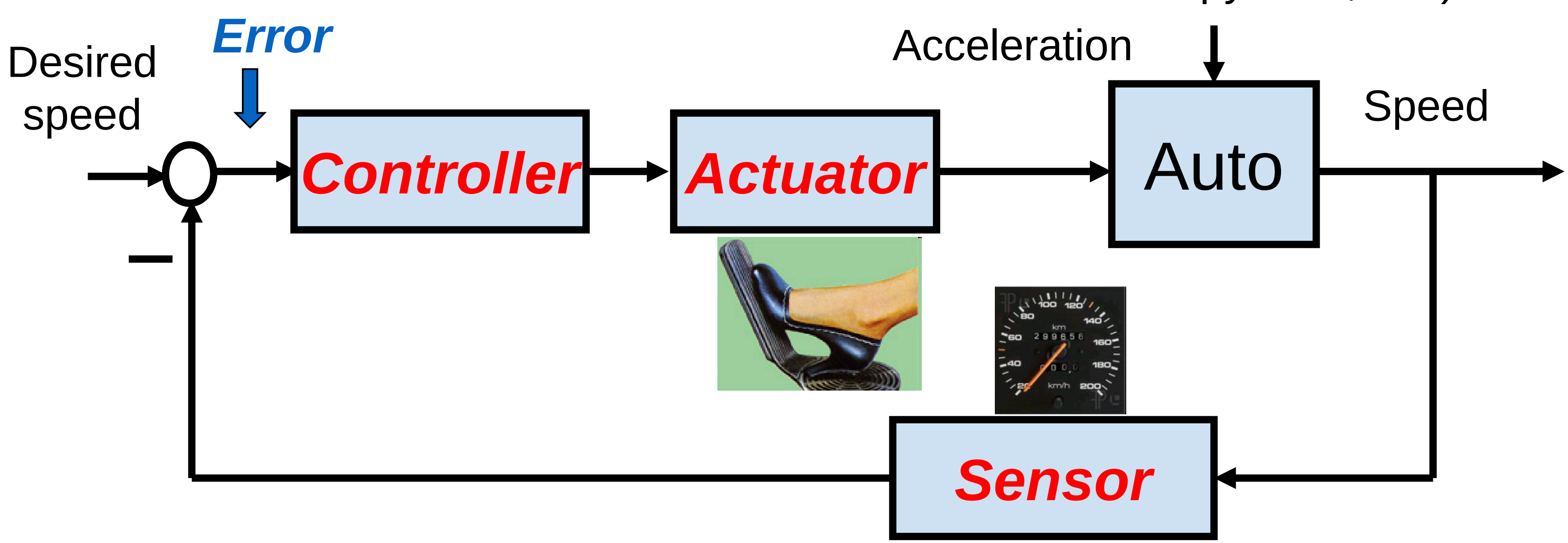
Block diagram



- Control with measuring devices (sensors) is called ***closed-loop (feedback) control***.
- Manual (not-automatic) control

Ex: Automobile cruise control

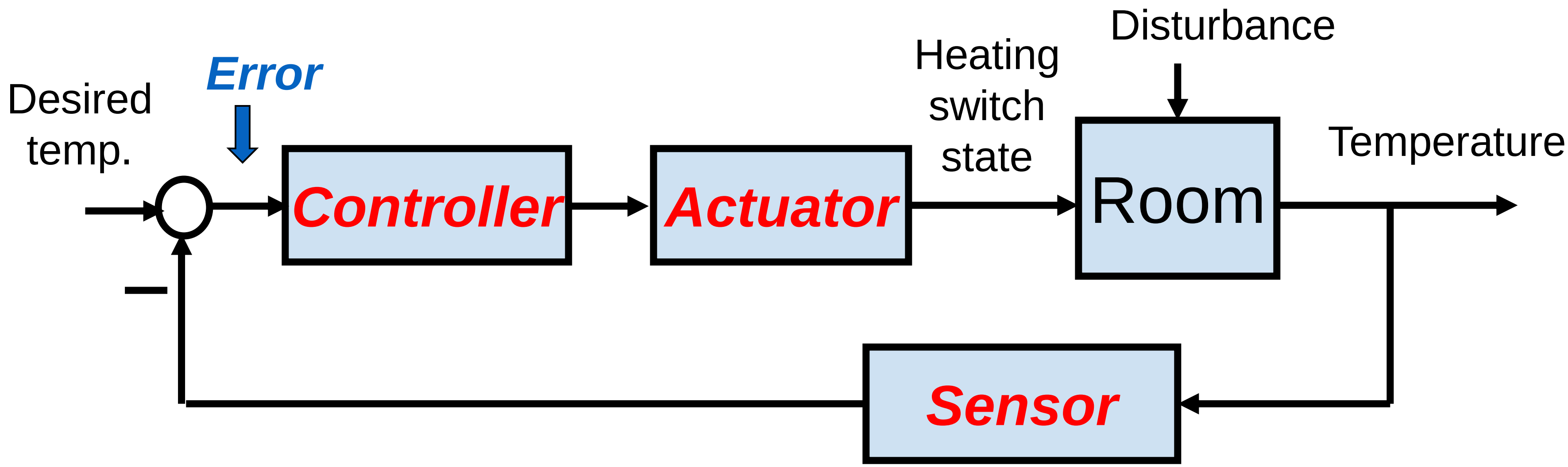
- Maintain the speed of the automobile.



- Cruise control can be both manual and automatic.
- When the controlled system is "Automobile", ***input*** and ***output*** depend on ***control objectives***, and not unique!

Ex: Room temperature control

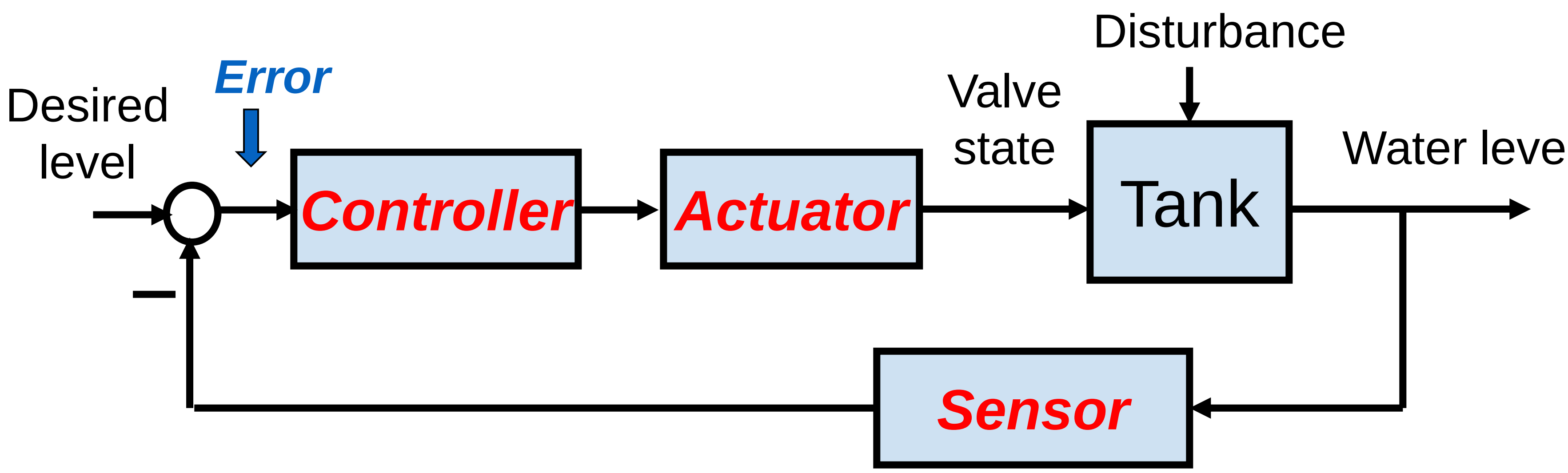
- Maintain the temperature in a room.



- Temperature control can be automatic.
- Note the similarity of the diagram above to the diagram in the previous slides!

Ex: Water level control

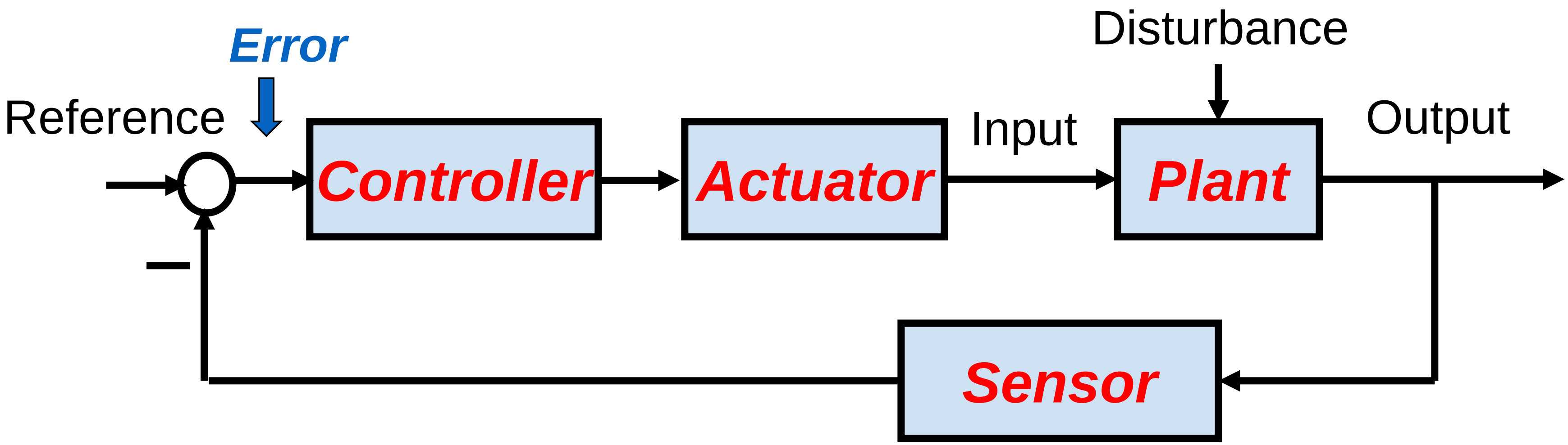
- Maintain the water level in a tank.



- Water level control can be automatic.
- Other examples: autopilot, catching a ball, etc.

Think about examples of feedback control by yourself!

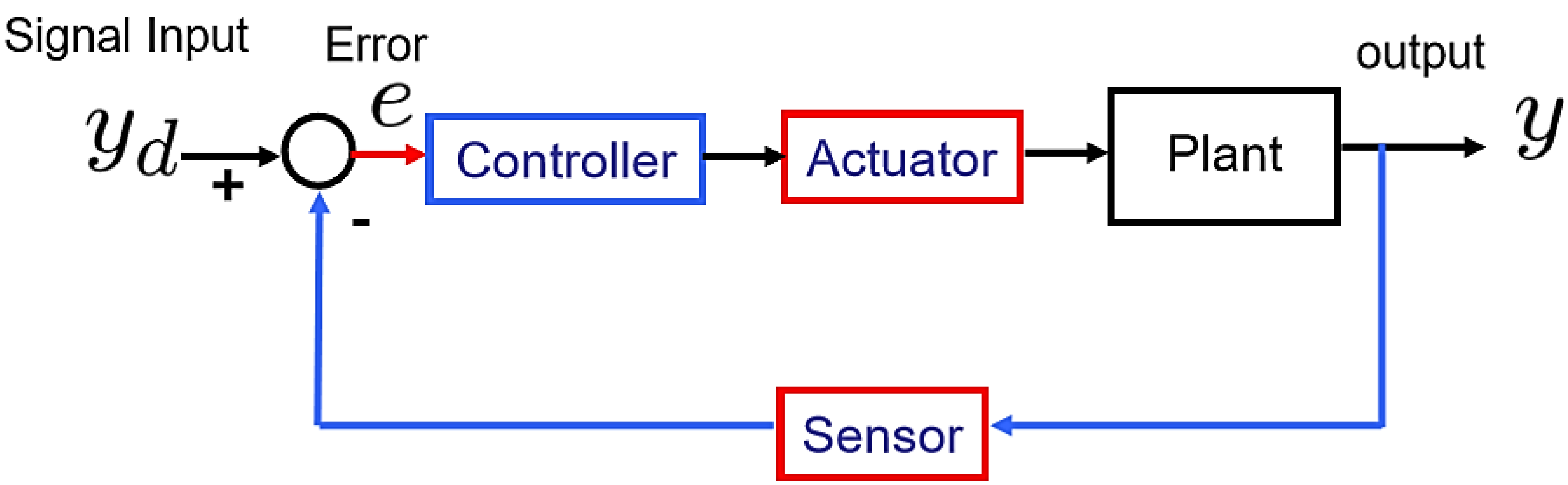
Automatic feedback control systems: Elements and design objective



- Control system design objective is to design a controller such that the output follows the reference in a “satisfactory” manner even in the face of disturbances.

Closed-Loop (Feedback) Control

- Compare actual behavior with desired behavior
- Make corrections based on the error
- The sensor and the actuator are key elements of a feedback loop
- Design control algorithm



Features of feedback control

- Advantage: Strong, or robust, against
  - uncertainty
  - unpredictable disturbance
  - variation of plant, etc.
- Disadvantage: The action is taken after some undesirable event happens and
  - the system becomes more complicated by the increased number of components, such as sensors and error detectors.
  - the system may not be stable (it may oscillate or depart greatly from the desired output), even though the comparable open-loop system is stable.

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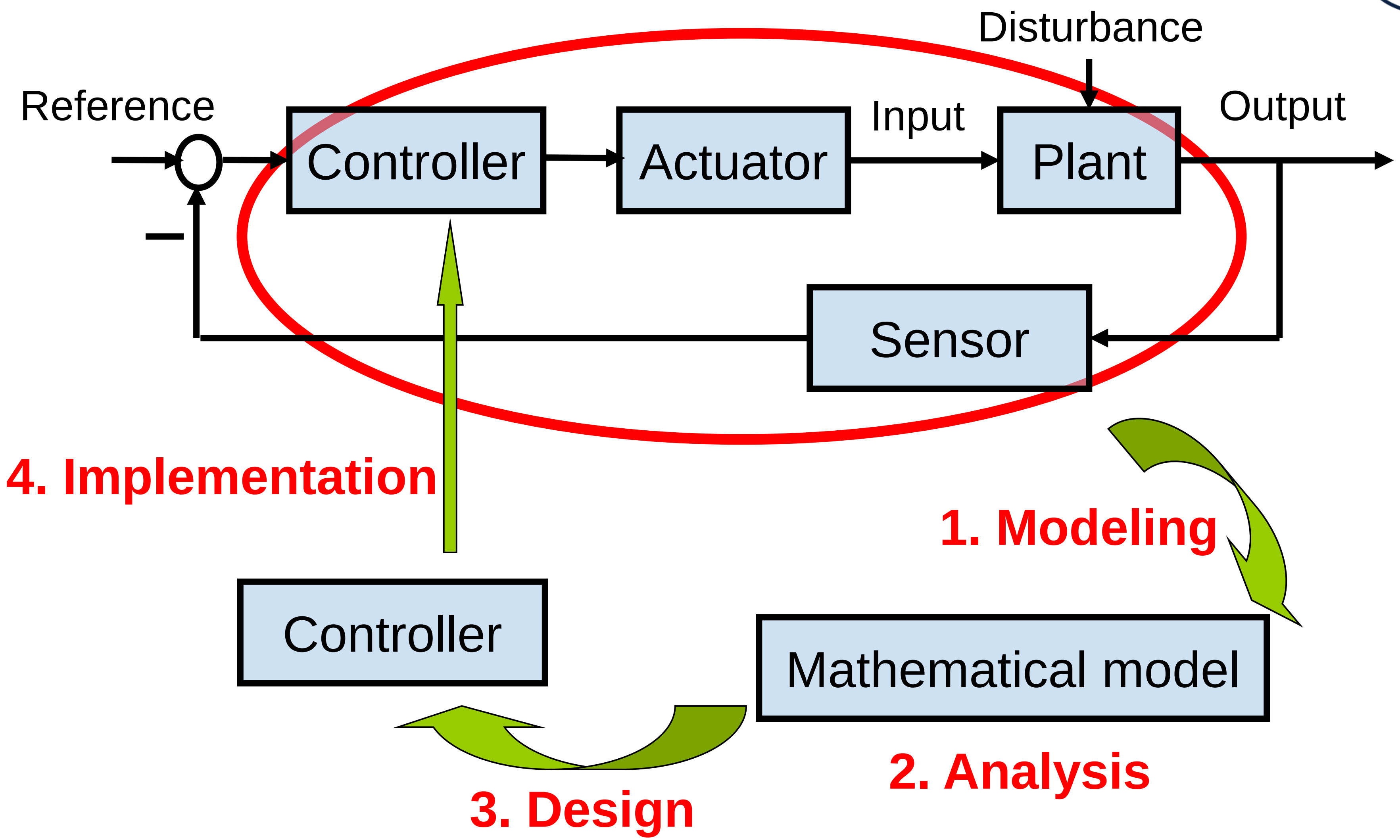
Systematic controller design process



Goal of this course

To learn basics of feedback control systems

- **Modeling**
  - Transfer function and a block diagram
    - Laplace transform (Mathematics!)
    - Electrical, mechanical, and electromechanical systems
- **Analysis**
  - Stability: Routh-Hurwitz criterion, and Nyquist criterion
  - Time response and frequency response
- **Design**
  - Root locus technique, frequency response technique, PID control, and lead/lag compensator
- **Simulation with Matlab**

Course roadmap

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Modeling

Laplace transform

Transfer function

Models for systems
- Electrical
- Electromechanical
- Mechanical

Linearization, delay

Analysis

Stability
- Routh-Hurwitz
- Nyquist

Time response
- Transient
- Steady state

Frequency response
- Bode plot

Design

Design specs

Root locus

Frequency domain

PID & Lead-lag

Design examples

Matlab simulations

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Summary

- Introduction
  - Examples of automatic control
  - Open-loop and closed-loop (**feedback**) control
  - Systems and control is useful and enjoyable!
- Next
  - Laplace transform