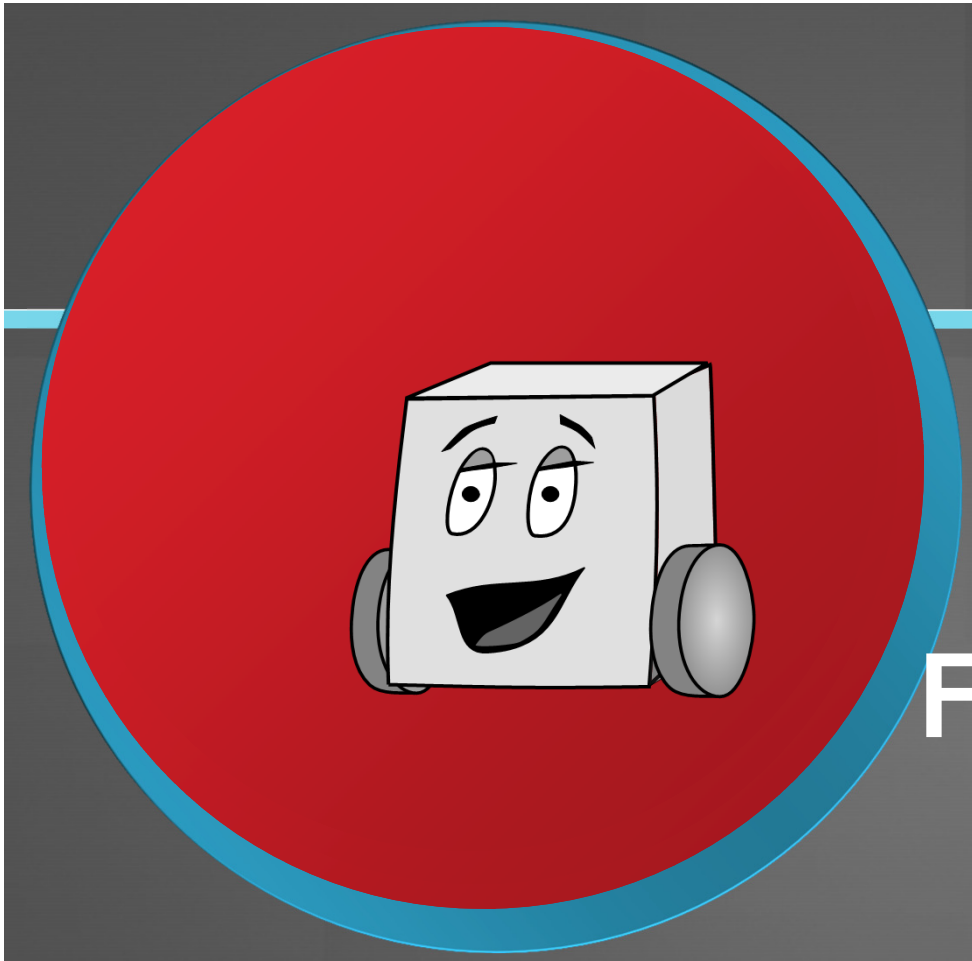


E11 Lecture 13: Feedback Control

Profs. David Money Harris & Sarah Harris

Fall 2011

Coming Up in E11

- This week's lab:
  - line-following robot
  - completed in teams (within same lab session)
- After fall break:
  - No lab week of 10/17
  - Line-following competition! (in class - Thursday 10/20)
- Game logistics and guest lectures:
  - 10/25: Game Kickoff!
  - 11/8: Game Scrimmage (in class)
  - 11/10: Underwater robots (Prof Levy)
  - 11/15: Batteries (Prof Hightower)
  - 11/17: Robotics Show and Tell (Prof Dodds)
  - 11/21: Final Game Competition!! (Monday, 5:30pm – Galileo)

E11 Lab Access

- Stay on our side of the curtain!
- Never be alone in the lab
- Keep lab door open when you're in it – make sure it's closed and locked when you leave, and turn lights off
- Don't remove anything from the lab
- Do not touch other people's robots/stuff
- Keep the lab clean and organized – throw away garbage, put stuff back where it belongs. The lab should look as good or better as when you got there!
- You may leave your robots/kits in the cubby holes in lab

Outline

- Robot Control
  - Open loop
  - Closed loop
    - Bang-bang control
    - Proportional control
- Developing Control Algorithms
  - What are algorithms?
  - How to represent algorithms
  - Example algorithms

Open Loop Control

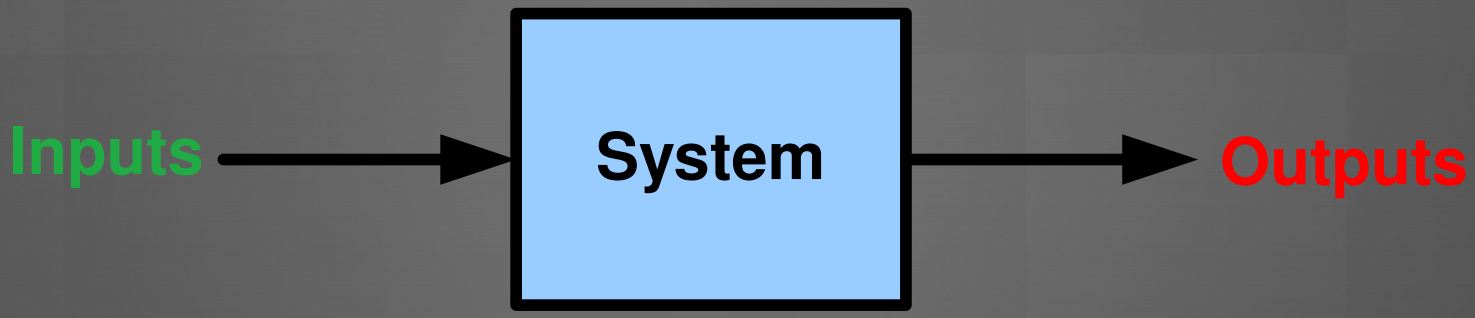
- Output activated according to preset rules, independent of environment
  - Example 1: sprinklers turn on for 30 minutes every morning, independent of current weather conditions (i.e., if it's raining, etc.)
  - Example 2: a heater turns on for 10 minutes every hour independent of current temperature.

Closed Loop Control

- Output is dependent on and affects inputs
  - Example 1: sprinklers turn on every morning until a desired moisture level is reached (as determined by a moisture sensor)
  - Example 2: a heater turns on until the thermostat reaches a desired temperature (as determined by a thermocouple)

Block Diagrams

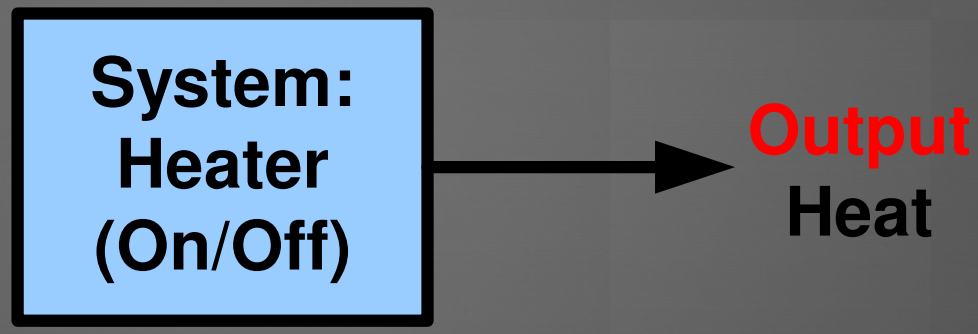
- Represent a system, inputs, and outputs



- Inputs: Detected by sensors
- Outputs: Generated by actuators
- Example sensors: Thermocouple, distance sensor, phototransistor, reflectance sensor, force plate
- Example actuators: Heater, motor, data collector

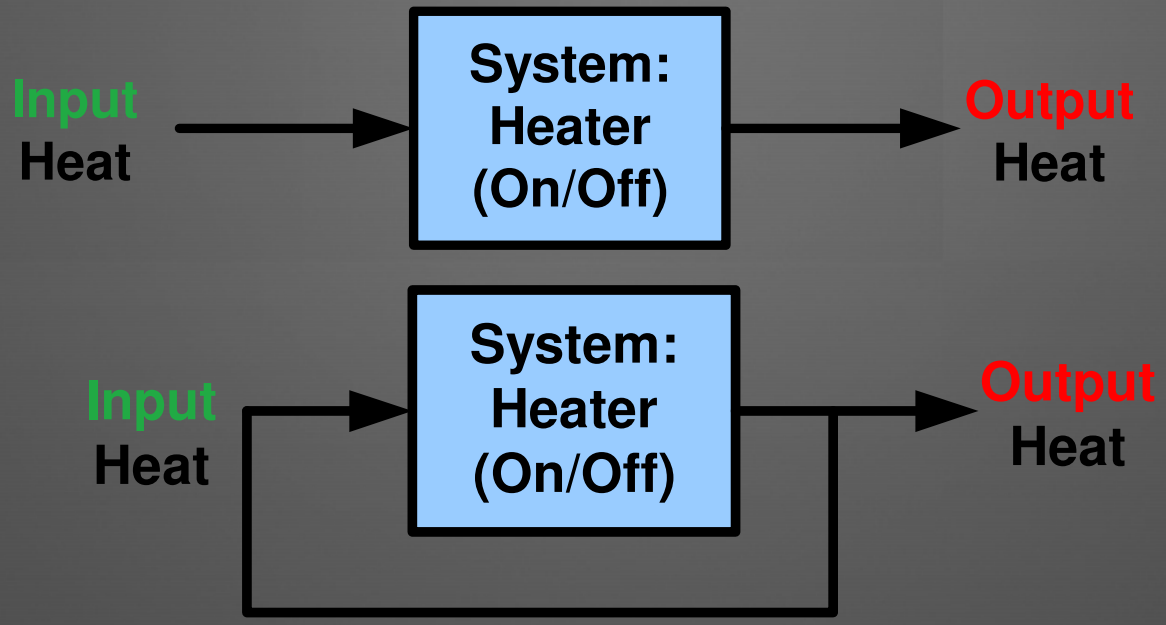
Block Diagrams

- Open Loop System



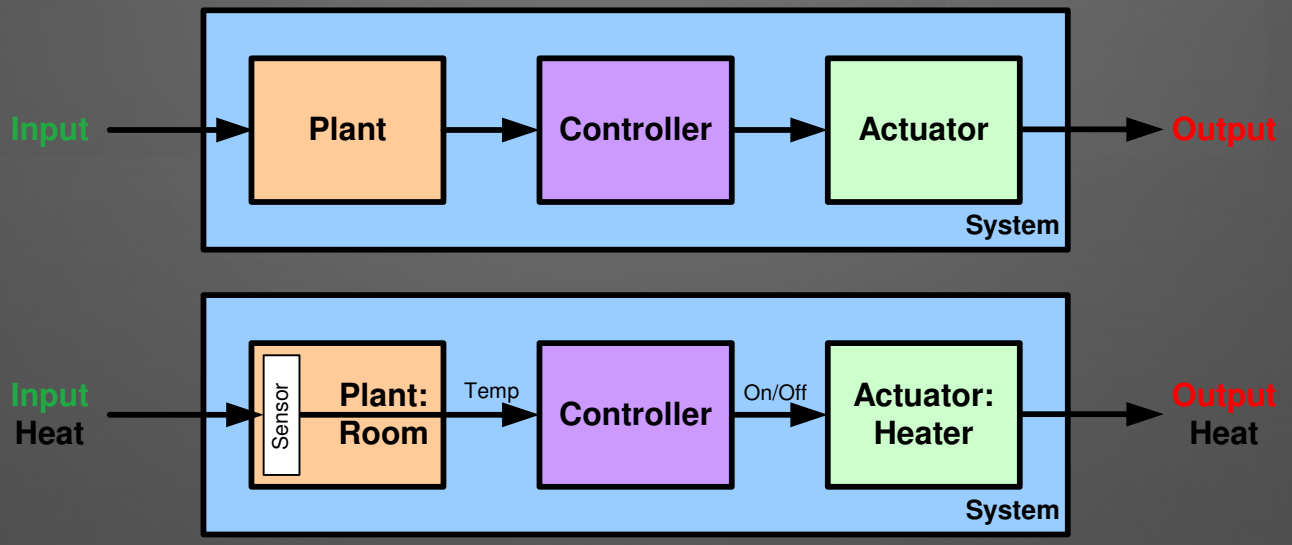
Block Diagrams

- Closed Loop System:
  - output affects input
  - input read (by sensor) to adjust output



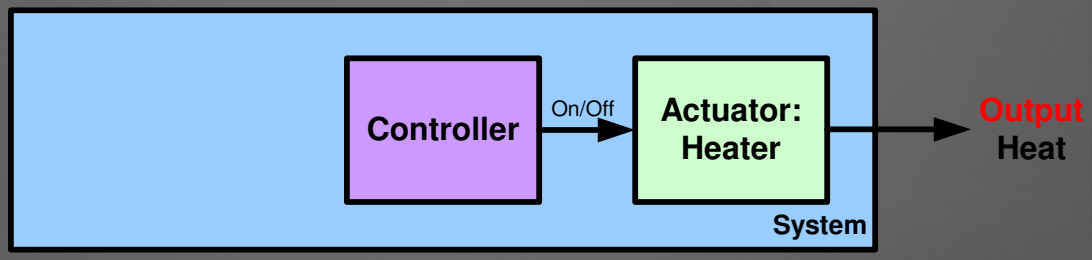
Control Example

- **Plant:** The room
- **Controller:** Receives input from plant, controls actuator
- **Actuator:** Heater



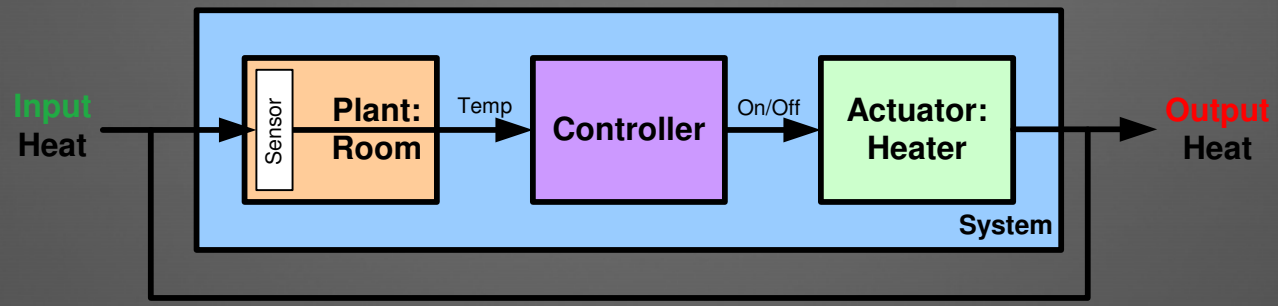
Open Loop Control

- Example: a heater turns on for 10 minutes every hour independent of current temperature.



Closed Loop Control

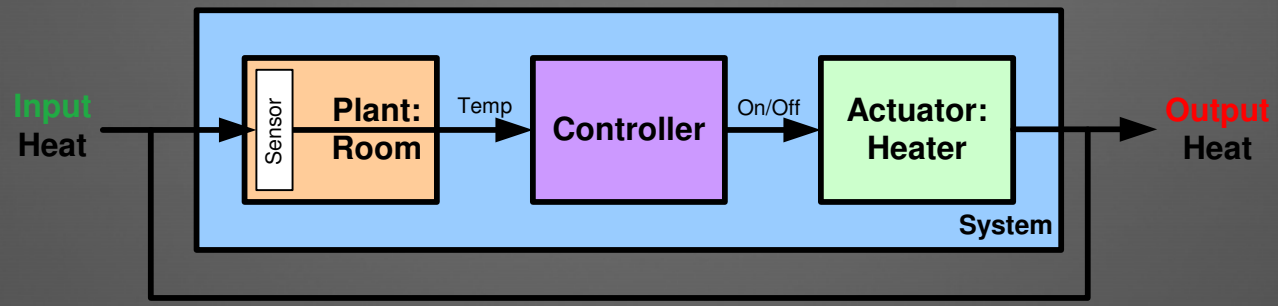
- Example: a heater turns on or off until the desired temperature is reached (as determined by a thermocouple).



Closed Loop Control is also called Feedback Control

Feedback Control

- Bang-bang digital control
  - The system checks the input (via a sensor), if it's not a desired value, the controller turns on actuator
  - Otherwise, the controller turns off actuator



Control Algorithms

- **Algorithm:** a sequence of steps needed to accomplish a goal
- Algorithms are frequently represented using **flowcharts**

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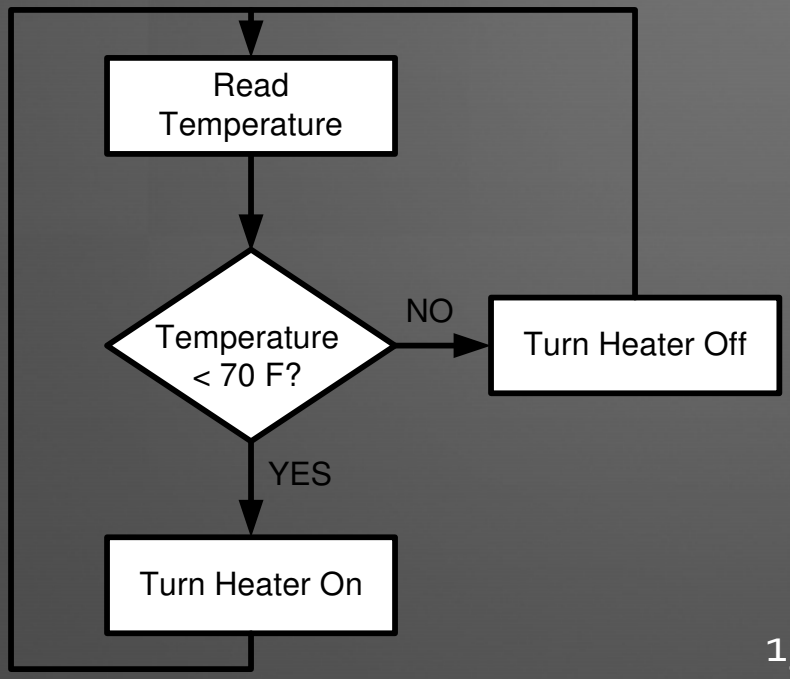

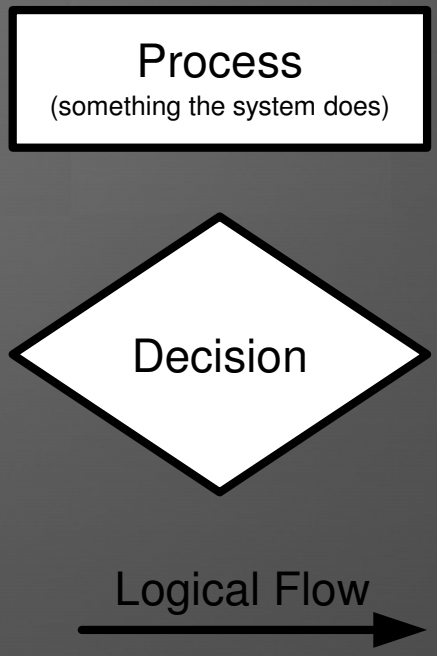

Control Algorithms

- Coding is done after designing the algorithm
- Problem solving
  1. State goal in words
  2. Create algorithm
  3. Code algorithm
  4. Test / debug
  5. Repeat steps 2-4 until satisfied

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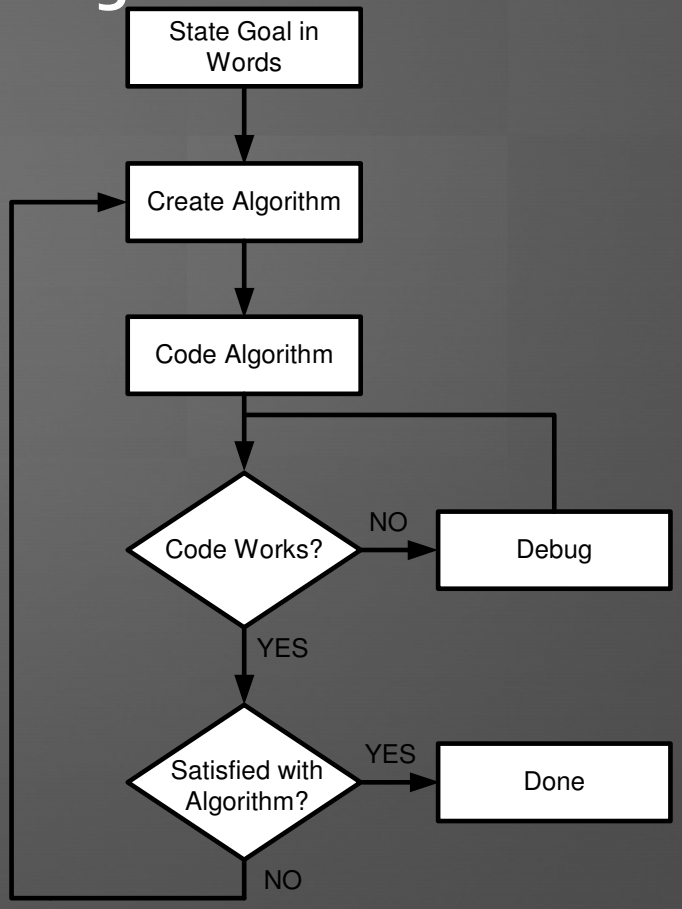

Algorithm Example 1

- Open Loop Control: Design an algorithm that turns the buzzer on twice a second for 10 ms. Draw a flowchart of your algorithm.

Algorithm Example 2

- **Closed Loop Control:** Design an algorithm that moves your robot toward the brightest light (among possibly multiple lights). The robot actively seeks the light.

Other Feedback Control Method

- **Proportional Control:** The system responds proportional to the error (desired value – measured value)
- **Example:** adjusting hot and cold faucets to get the desired temperature
  - If the temperature is much colder than desired, the hot water faucet is opened a lot (proportional to desired-measured temp)
  - If the temperature is slightly colder than desired, the hot water faucet is only opened a little (proportional to desired-measured temp)

Algorithm Example 3

- **Closed Loop Control:** Use proportional control to design an algorithm that turns the heater on depending on the difference between the desired and detected temperature.

Algorithm Example 4

- **Closed Loop Control:** Use proportional control to drive your robot up to an object as fast as possible without hitting it. (When your robot reaches the object, it should stop ☺)

Summary

- Open Loop Control:
  - System function does not affect the inputs
- Closed Loop Control:
  - System function affects the inputs
- Types of Feedback Control:
  - Bang-bang control: the system turns on (does something) until a desired value is reached
  - Proportional control: the system responds proportional to the error (desired – measured)
- Algorithm: Sequensce of steps needed to accomplish a goal
- Flowchart: Graphical representation of algorithm
- Algorithm Design: start simple!!!