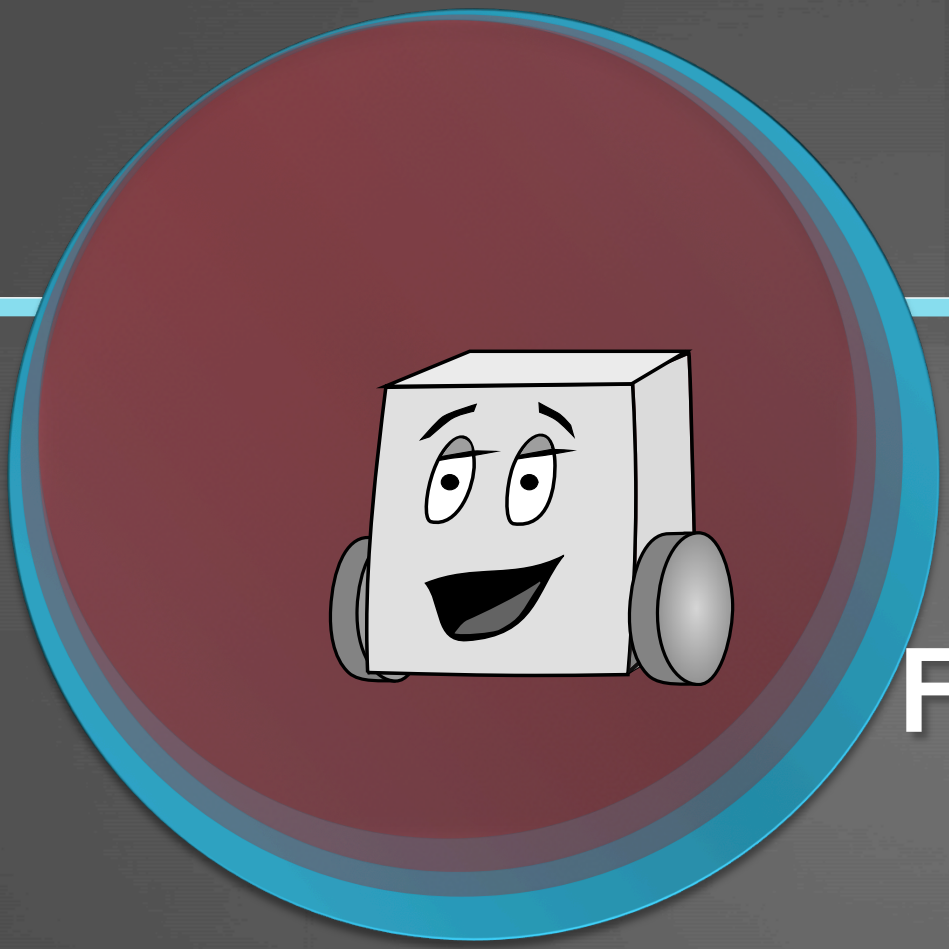


E11 Lecture 13: Feedback Control

Prof. David Money Harris

Fall 2014

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 10/20 ☺
  - Line-following competition! (in class - Thursday 10/23)
- Game logistics
  - 10/28: Game Kickoff!
  - 11/20: Game Scrimmage (in class)
  - 11/25: Final Game Competition!! (Monday, 5:30pm – Big Shanahan)

E11 Lab Access

- The door code is: 2 – 14 – 3 (Parsons B171)
- Stay on our side of the curtain!
- Never work 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
- Supply cabinet access via proctors only
- 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

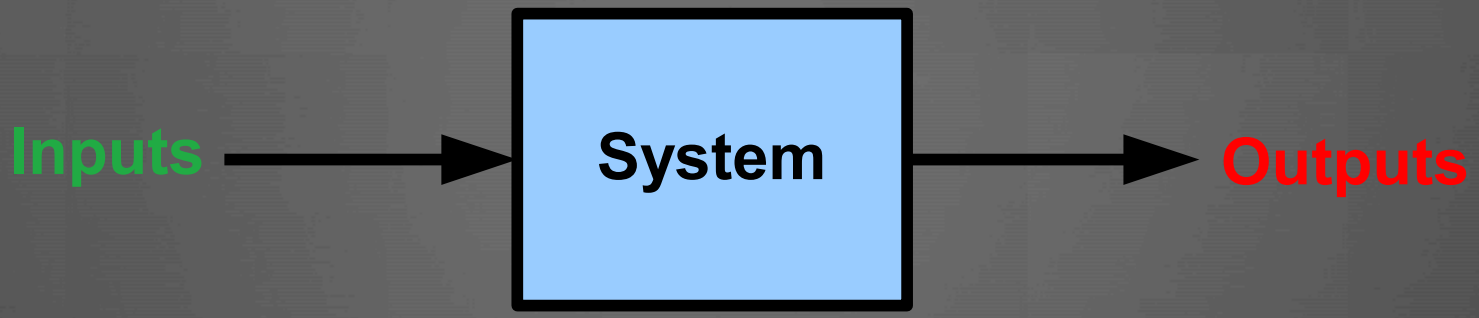
- Output activated according to preset rules, independent of environment
  - Example 1: a heater turns on for 10 minutes every hour independent of current temperature.
  - Example 2: robot drives both motors forward at full power for 5 seconds.

Closed Loop Control

- Output is dependent on and affects inputs
  - Example 1: a heater turns on until the thermostat reaches a desired temperature
  - Example 2: a robot drives both motors forward at full power until the distance sensor indicates that the wall is more than 6" or less than 4" from the bot

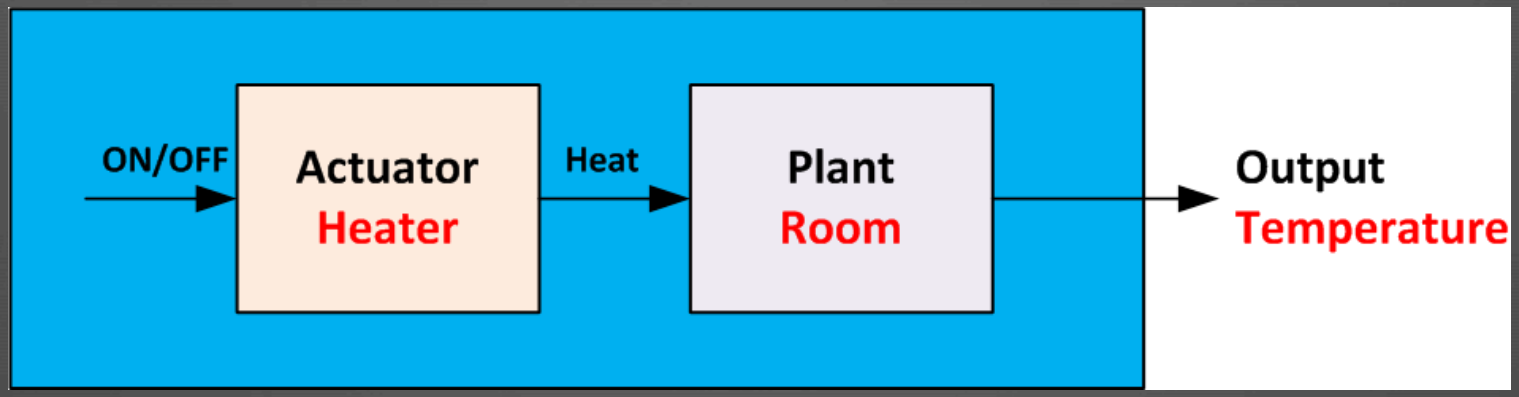
Block Diagrams

- Represent a system, inputs, and outputs



Open Loop Control

- Example: a heater turns on for 10 minutes every hour independent of current temperature.
  - Input: none
  - Output: room temperature

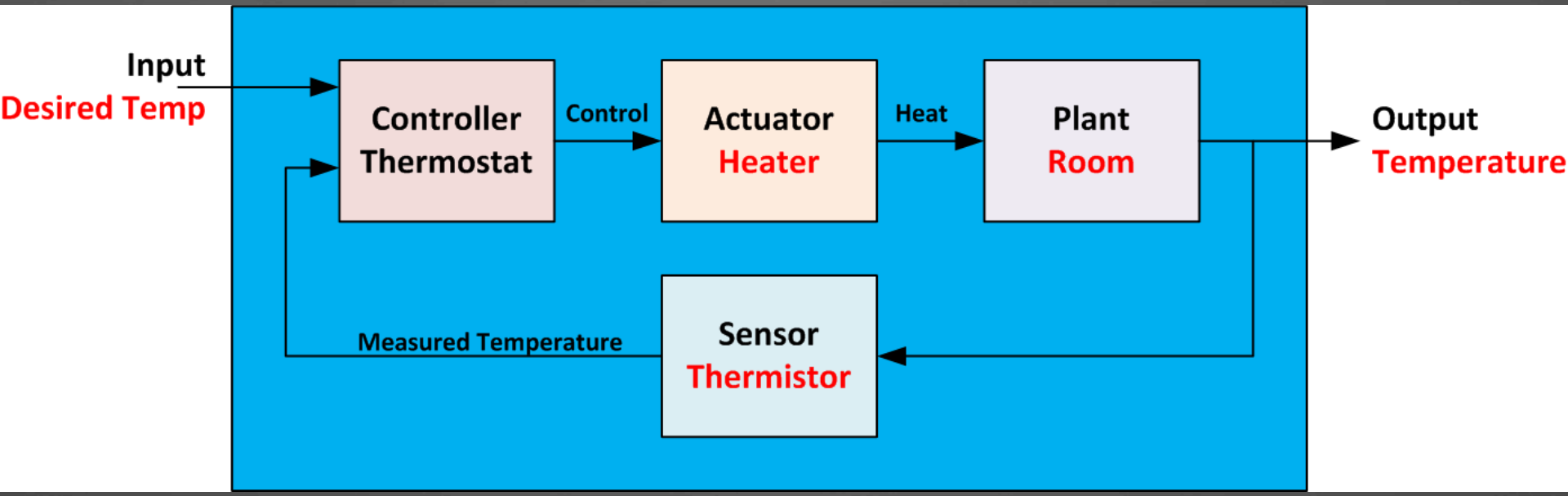


Open Loop Drawbacks

- The output is unpredictable. Influenced by
  - Ambient temperature
  - whether windows open
  - Strength of actuator: Has the heater been serviced lately?

Closed Loop Control

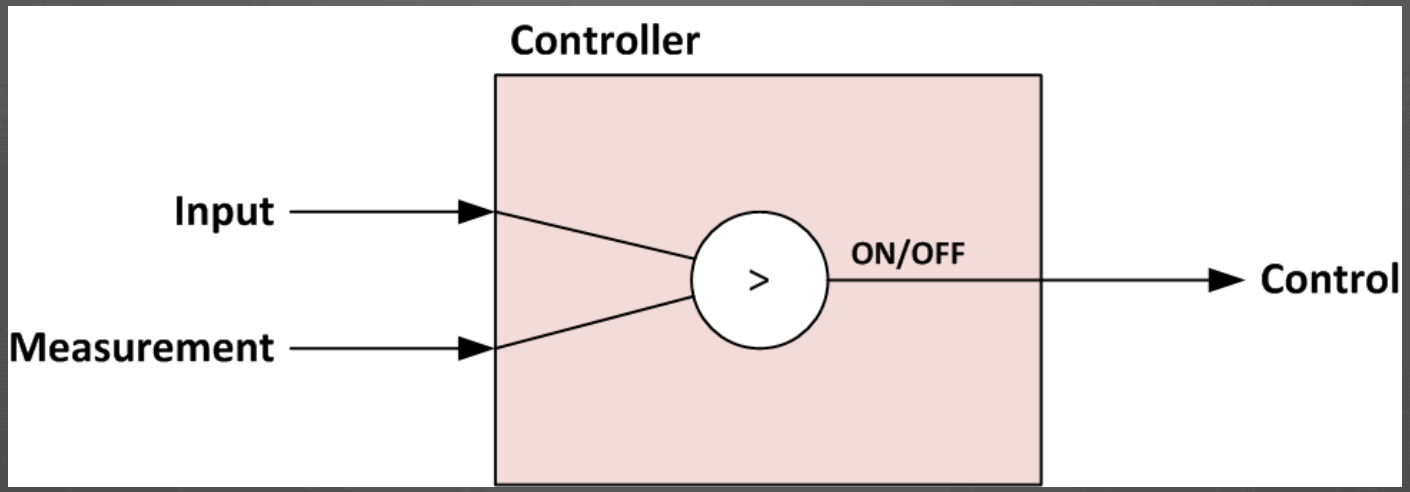
- Example: heater turned on until temperature reached
  - Input: desired temperature



Closed Loop Control is also called Feedback Control

Bang-Bang Digital Control

- Turn the actuator fully ON or OFF.
  - If output is less than desired, turn actuator ON
  - If output is more than desired, turn actuator OFF

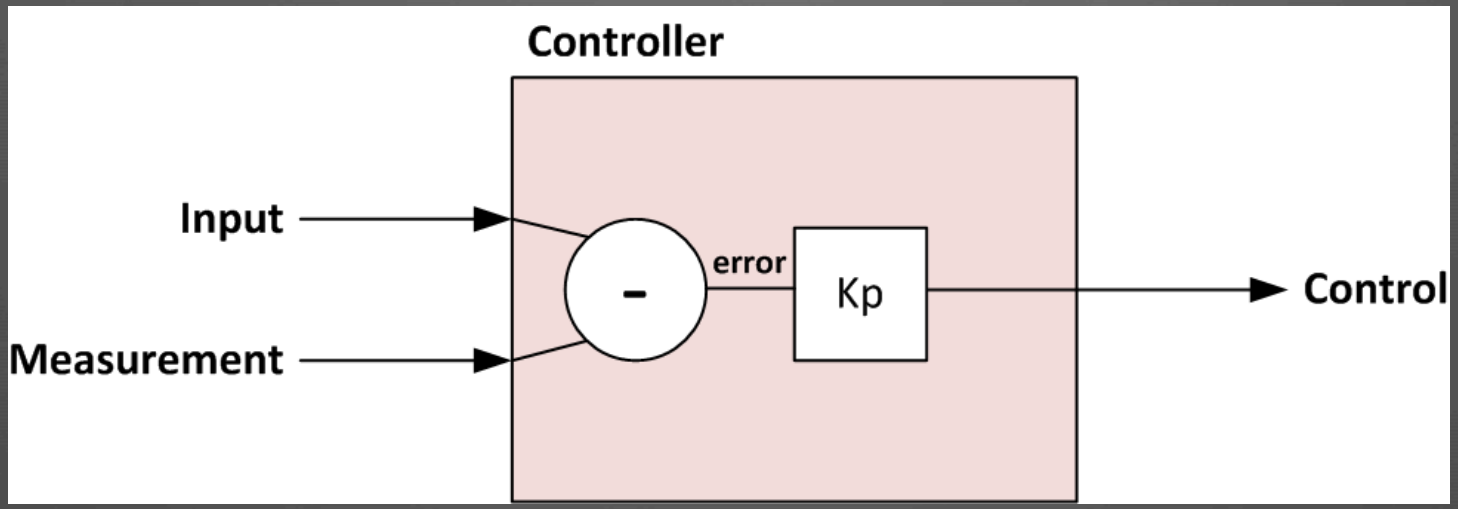


Bang-Bang Control

- Advantages:
  - Very easy to design with software
  - Intuitive
- Disadvantages
  - Steady state error
  - Overshoot

Proportional Control

- Power the actuator proportionally to difference between input and measurement
  - Called the error



Proportional Control

- Advantages
  - Easy to build with analog circuits
    - Operational amplifier
- Disadvantages
  - Steady state error
  - Overshoot

PID Control

Tradeoffs

- Bang-bang control is easiest in software
  - Most E11 robots use bang-bang
- PID is more capable
  - Implement with software or hardware
  - Correct for overshoot and steady state error
- Advanced control algorithms can correct for more complex actuator and plant responses
  - E102 covers PID and modern control

Example: Wall Following

Control Algorithms

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

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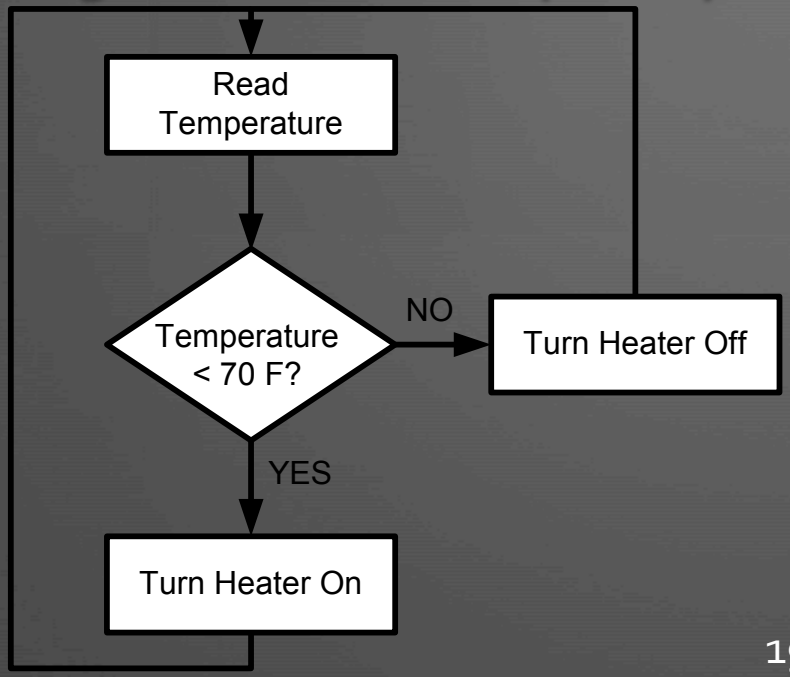

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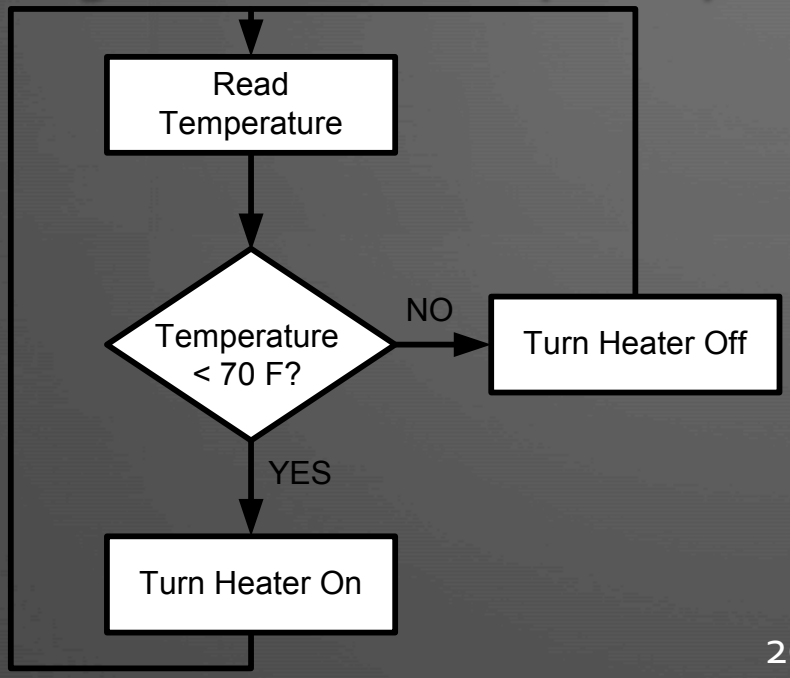

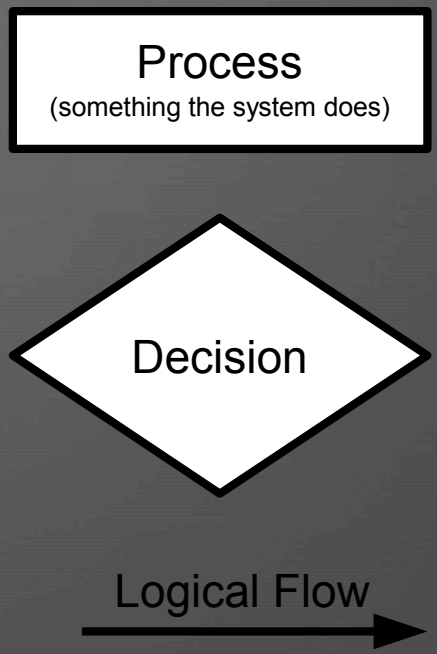

Control Algorithms

- 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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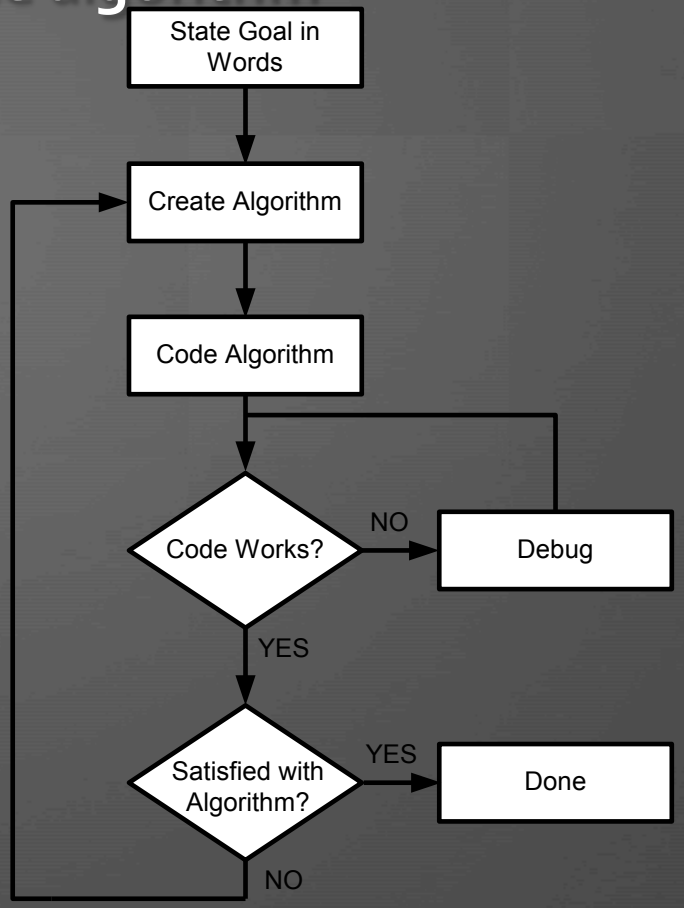

Algorithm Example 1

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

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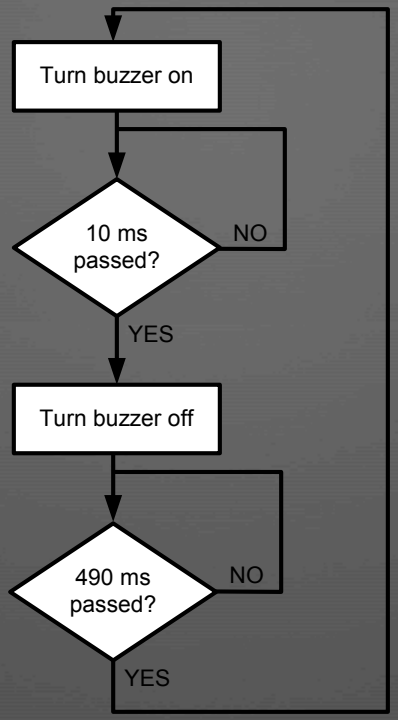

Algorithm Example 2

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

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