Control 1

Materials

Hand mirrors (one per pair of students)

Handouts:

The Human Balance System
Regulation of Light Input, Breathing, Heart Rate and Body Temperature
How is body temperature regulated and what is fever?
Control Systems

Resources

Toilet system videos
Flushometer: https://www.youtube.com/watch?v=x9XHI4lpPVE
Tank toilet: https://www.youtube.com/watch?v=hAxAyoSMQhI
https://www.youtube.com/watch?v=LzFIPUJghsQ

1) Control systems in your body

Individual activity:

Stand on one foot. How long can you stay like that? Now close your eyes. What happens and why?

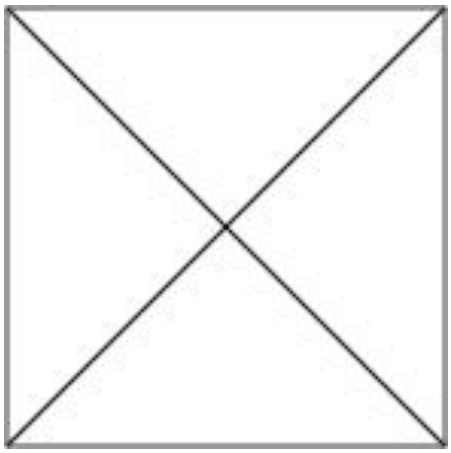
Group activity

Stand with one side next to a wall. Lift the foot that is away from the wall. What happens? To answer this work in pairs. One person stands on one foot (away from the wall), while the other observes. Then switch roles. What do you have to do in order to stand on one foot? What makes you do it?

Notice that as you stand on one foot, you automatically shift your weight to the other side, in order to maintain your balance. This is the result of a feedback control system. Feedback from your eyes and other sensors in your body tell you that you are about to fall. Without thinking about it, your brain corrects this situation by forcing your body to shift your weight to the other side, so that your center of gravity remains above the base.

Group Activity

Draw a square with both diagonals:



Place a mirror on the table, and have your partner prop it up so you can see the square clearly in the mirror. Then try to trace it, looking at it only in the mirror.

Project

Touch your toes (as close as you can). Now stand with your back to the wall. Can you still do it? Now observe someone else touching their toes away from the wall. Describe what happens and why.

Group project

One group member measures another's pulse rate before and after exercise.

Questions for discussion

- What happens to your heart rate and breathing rate while you exercise, and shortly afterwards?
- How do your eyes adjust to low and high levels of light?
- What keeps your body temperature at around 98.6°F?

2) Open vs closed loop control: Does system check output to how close it is to goal? No = open loop; yes = closed loop. Every control system, whether open or closed loop, uses information to control the flow of energy. In an open loop system, the user supplies the information, and uses it to turn on a stove, a faucet or a light.

   Group activity: Compare open and closed loop control systems that have similar functions, such as sink vs toilet; stove vs microwave; light switch vs motion or daylight sensor; automatic shutoff vs. conventional steam iron; cruise control vs manual accelerator; lecture vs. class discussion.

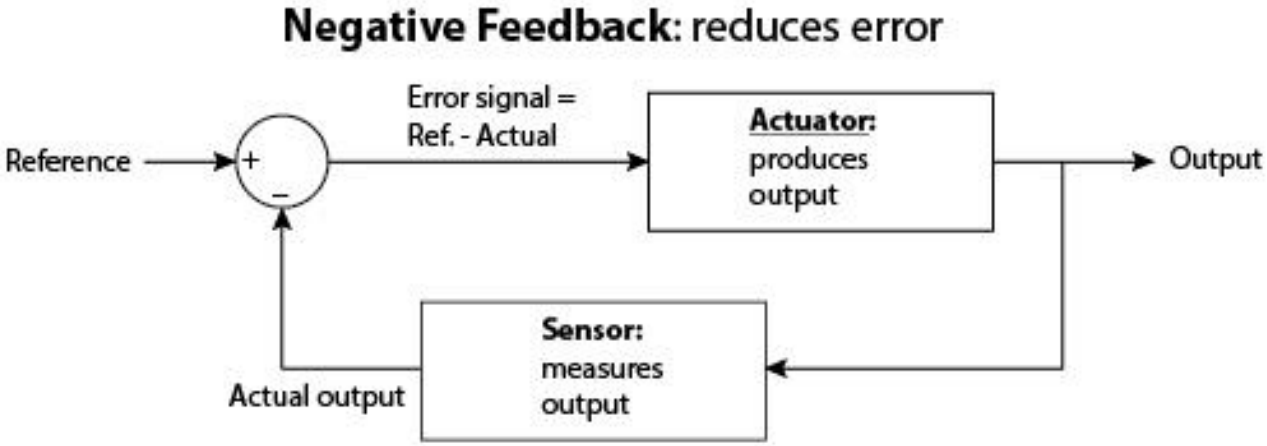
3) Positive vs negative feedback: Demonstration: "you stepped on my foot!"

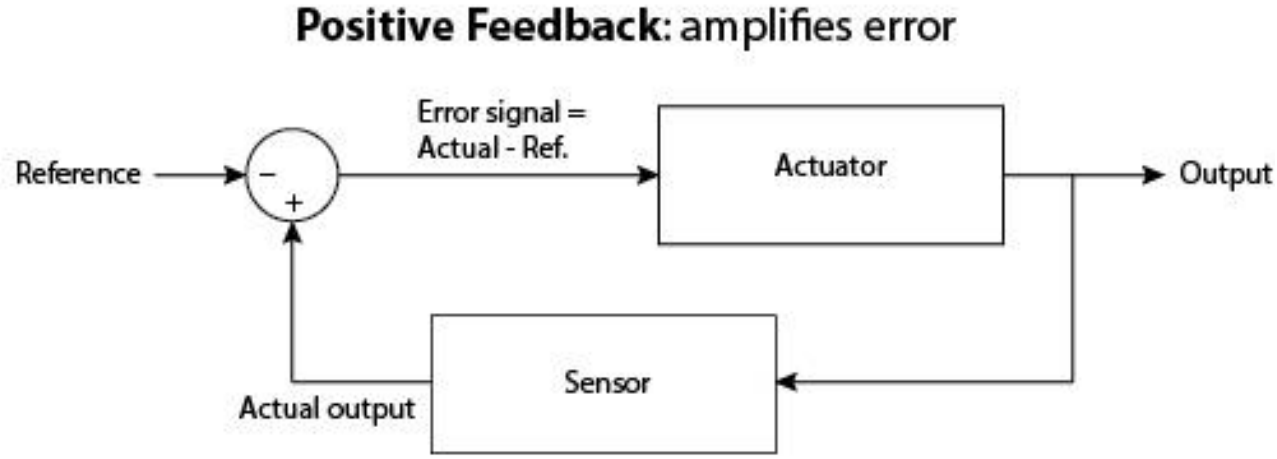
   Discussion: Identify examples of both open and closed loop control from everyday interactions

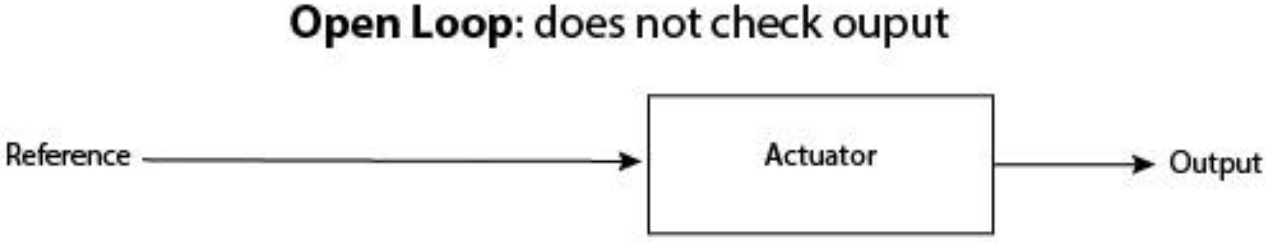
4) Components of a control system

   - Variable: The quantity is the control system is trying to affect.
   - Goal: The effect the system is trying to have on the controlled variable.

- Reference: Desired value of the controlled variable
- Actuator: Produces the output of the variable under control
- Sensor: Measures the output value of the variable
- Comparator (circle to the left): Compares actual value of the variable with the reference
- Error signal: Difference between actual and reference values produced by the Actuator







5) Control in the human body

Your body uses feedback control systems to regulate i) balance, ii) motion control, iii) heart rate, iv) respiration rate, v) light input to the eyes and vi) body temperature, among many others. In each case, the control system is organized to accomplish a specific goal. It does so by monitoring how close or far it is to the goal, and then adjusting its output to reduce the difference between the actual output and the goal. The desired state is called the reference, monitoring is done by a sensor, and the loop is closed by an actuator, whose job is to move the output closer to the reference.

Class activity

For each of the control systems mentioned above, identify the goal, the variable under control, the reference, the sensor and the actuator. Ref.: B. Hassenstein, Information and Control in the Living Organism, pp. 42-58. See Table 1.

6) Final Project Group Meetings

BREAK BETWEEN SESSIONS

7) Feedback in engineering systems: Scavenger hunt and brainstorming: find control systems in the bathrrom, hallway, classroom. For each one, identify the variable that is controlled, the type of system (engineered or mixed; open or closed loop), reference level, sensor and actuator in each of the control systems you find (see Table 2).

8) Natural vs engineering systems:

Project: Compare natural and engineered systems for either a) light control to eyes vs. automatic camera; b) body temperature vs indoor climate control; c) manual vs. automatic control of lighting d) use of fire extinguishers vs. automatic sprinkler systems. Compare these according to mechanisms of operation, precision, speed and stability.

9) Final Project Meetings

Table 1: Natural Feedback systems in the human body

System	Goal	What is controlled?	Reference	Sensor	Actuator
Balance	Avoid falling	Location of center of gravity	Center of gravity above the base	Vision; motion of fluid in semicircular canals of inner ear	Brain, nerves & muscles
Control of hand motion	Trace a figure on paper	Location of hand	Location of drawn line	Vision, processing by brain	Brain, nerves and muscles
Heart	Provide sugar to muscles	Pulse rate	Blood flow needed by muscles	Lactic acid buildup in bloodstream	Dilation of capillaries, increase in heart rate
Respiration	Balance $C0_2$ & 0_2 levels in blood stream	Breathing rate	Normal blood levels of $C0_2$ & 0_2	Blood $C0_2$ monitor	Muscles that move the chest wall and diaphragm, controlling rate and depth of breathing
Light input	Enable visual information processing	Light input to retina	Light input for normal vision	Retinal rod cells, output to brain through optic nerve	Muscles of iris dilate or contract pupil
Internal temperature	Enable metabolism	Body temperature	98.6°F.; higher in case of illness	Hypothalamus	Dilate or contract capillaries; activate sweat glands; metabolism of fat; random muscle movements (shivering)

Table 2: Feedback systems involving engineering

System	**What is controlled?**	**Open or closed loop?**	**Analog or digital?**	**Reference**	**Sensor**	**Actuator**
Mouse trap	Life of mouse	closed	digital	Dead mouse	Trigger below bait	Spring and lever
Shower temperature	Water temperature	open	analog	body temperature or slightly higher	Temperature receptors in body	Hot and cold water faucets
Indoor climate control	temperature	closed	digital	Set by thermostat	Thermometer	Furnace or central air
Toilet	Water level in tank	closed	analog	Maximum float level	Float and lever	Cold water supply valve
Steering a car	Direction of car	open	analog	Direction of road	Driver's vision	Steering wheel and mechanism
Automatic camera	Light input to film or light sensors	closed	digital	Light input for proper brightness and contrast	Internal Light meter	Shutter speed, diaphragm
Manual camera	Light input to film or light sensors	open	both	Light input for proper	Internal or external light meter	Shutter speed, f stop
Elevator	Floor location	closed	digital	Floor button pressed	Floor sensor	Motor, counterweight and pulley system