

Big Idea (Week 11): Sensing and Actuation

Our digital computers can sense and manipulate the physical world. This allows the automated machines we build and program to interact with the world and control it. Coupled with digital communication, it allows us to observe and control the world at a distance. This capability is the basis of life-saving devices like pacemakers, safety mechanisms like anti-lock brakes, and, ultimately, robots and self-driving cars.

The ones and zeros we compute can be used to switch transistors and relays that turn on or off electrical and electromechanical devices like lights, heaters, and motors. By controlling the flow of electrical currents, we can selective magnetize or demagnetize components to create motion. With fine control, we can adjust the strength of the current or the periods of on and off time to control speed of motion or applied force.

Perhaps the simplest sensor is a switch that provides a zero or one based on whether it is open or closed. This can be used to sense the presence or absence of something in the physical world. Growing more sophisticated, we can build devices to turn positions, force, and illumination into voltages that we can discretize with Analog-to-Digital converters into quantized numbers for use in our calculations. Digital cameras take illumination further, capturing maps of light intensity that we turn into voltages and bits to create the raw input from which we can begin to program our machines to “see” the physical world.

Combining sensing and computation with actuation, we can precisely control actuation despite variable behavior from our components or noisy disturbances from the world. Rather than turning on a motor for a fixed period of time, we can sense the position of the motor or actuation and use that in algorithms to decide how much further to actuate the motor and in which direction. Servos provide an example, where we can specify an angular position, sense whether the servo shaft is short or past the desired position, and use that input to further actuate the servo motor to move it closer to the desired position.