

University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

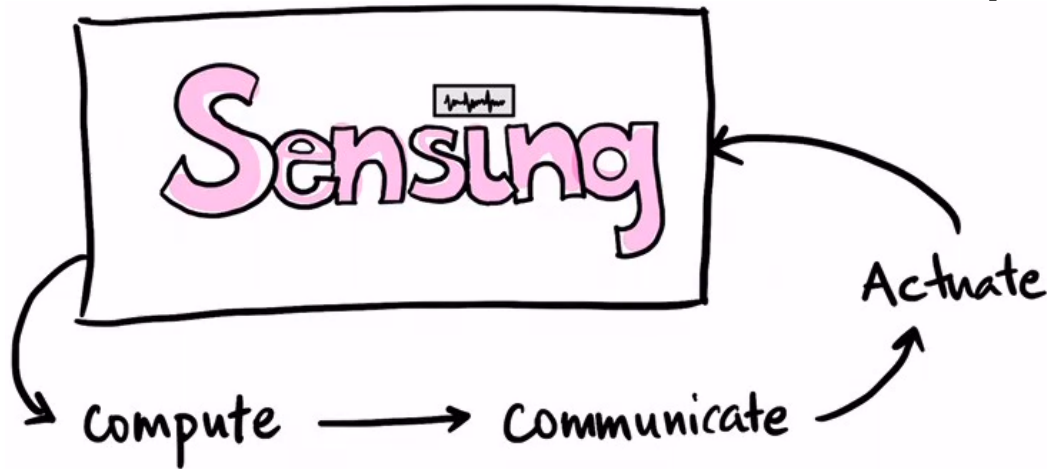
ECE 101: Computing Technologies and the Internet of Things

Sensing (part 1 of 2)

Technologies of Today and Near Future

Many technologies share this theme of a

Sense-Compute-Communicate-Actuate
loop.



Sense-Compute-Communicate-Actuate Loop

- **Sense**: Use sensors to pick up signals - get information about the environment
- **Compute**: Use computation using that information
- **Communicate**: Send results of computation (or some of the sensed information) to other systems or to humans
- **Actuate**: Take some action: physically move (with help of motors) or send a signal
- **Loop**: Go through the four-step process again and again

Sense-Compute-Communicate-Actuate Loop

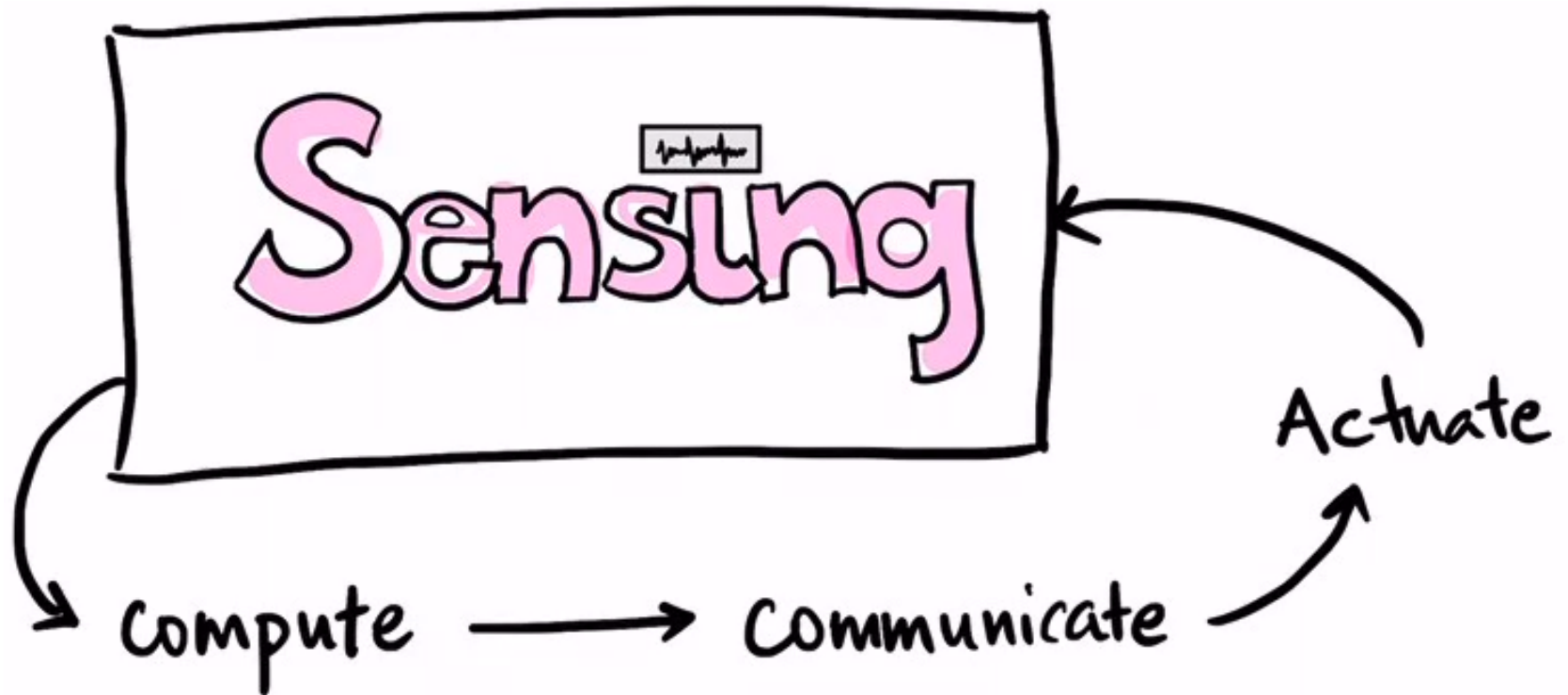
Actuation means that the machines control something physical in the real world.

Once a machine

- actuates changes,
- the machine must observe the results.



Today's Topic: Sensing



Theme: Sense-Compute-Communicate-Actuate Loop

We want “smart” machines that are able to do similar things as humans.

Sense:

- eyes,
- ears,
- touch/feel,
- taste, and
- smell



Theme: Sense-Compute-Communicate-Actuate Loop

Computing happens in the brain.

It's separated into parts:

- visual cortex,
- auditory cortex,
- somatosensory cortex,
- motor function,
- and more



Theme: Sense-Compute-Communicate-Actuate Loop

- Once the brain makes a decision,
- we **communicate** through facial expressions, motions, gestures, voice
- finally, we may **actuate** through muscular and skeletal movements.



Theme: Sense-Compute-Communicate-Actuate Loop

Can we replicate that process (the loop)?

Can we get the robot to do a high five?

What happens next?

Do the loop again!
(actually happening continuously)



Boston Dynamics humanoid robot Atlas

The Loop in a Machine: Drone Delivery Systems

Technology need not be humanoid.

Consider a drone that drops off emergency supplies after a catastrophic event (these exist now).

What are the elements of the loop?

- **Sense:** environment conditions, location via GPS
- **Compute:** process sensed data, decide what to do
- **Communicate:** with other drones, base camp, destination
- **Actuate:** control rotors to land safely or hover, deposit package safely.

Start over—go get another package!



<https://youtu.be/88yQTzImsiA?si=Ixx0mO3HNNdUirgD>

The Loop in a Machine: Autonomous Vehicles

- **Sense:** surroundings (Camera, LIDAR, GPS)
- **Compute:**
 - processing images, audio, video
 - identify objects
 - Location information
- **Communicate:** with human or cloud
- **Actuate:** turn wheels, speed up, slow down, change lanes, turn signal, brake, basically drive the car

Loop continuously!



The Loop in a Machine: Robot Farmers (!)

Pick tomatoes only if they are ripe!

- **Sense**: appearance, softness
- **Compute**: ripeness-ready to pick?
- **Communicate**: to human farmer
- **Actuate**: pick the tomato without hurting the plant.

Loop—move on to next tomato/
plant



The Loop in a Machine: Digital Assistants

Sense: voice command (wake word)

Compute: speech to text

Communicate: with web/cloud resources/customer to get answers or additional information,

Actuate: transform results into human speech and output to speaker; turn on light/screen



The Loop in a Machine: Cleaning Robots

These clean while mapping the rooms

Initially, the robot

- moves almost randomly
- to explore the house.
- once it has an idea of the layout and has created a map,
- it can use the map for more careful future movement.



Called **SLAM**: Simultaneous Localization and Mapping

Cleaning Robot: What are the Loop Elements?

Sense: distances to walls/obstacles

Compute:

- how long until collision given current motion direction + speed?
- build map of space (may need adjusting if you just bought a table!)
- what parts of the floor are clean?
- how can the robot reach parts that aren't clean (path planning, given dynamics of robot)?
- can it use a path that doesn't go over the same parts of the floor repeatedly?



Cleaning Robot: What are the Loop Elements?

Communicate?

Maybe not, unless multiple robots

- are coordinating to clean a house
- without overlapping work,
- trading map information, and so forth.

Actuate: change directions, speed; move around (wheels, motor), clean (suction control)

Example: Smart Treadmill

What are the Loop Elements?

Sense:

Compute:

Communicate:

Actuate:

Example: Smart Treadmill

What are the Loop Elements?

Sense: how fast am I walking? What's my heart rate?
Is my gait even?

Compute: answers to questions, calories burned, track
your exercise plan

Communicate: to smart watch/activity trackers so
that they share information

Actuate: control speed, control angle relative to floor,
play music

Today: Let's Look at Sensing

We've talked about **computing**.

We've talked about **communication**.

Actuation gets into control and robotics, so we won't go too deeply into those topics ...

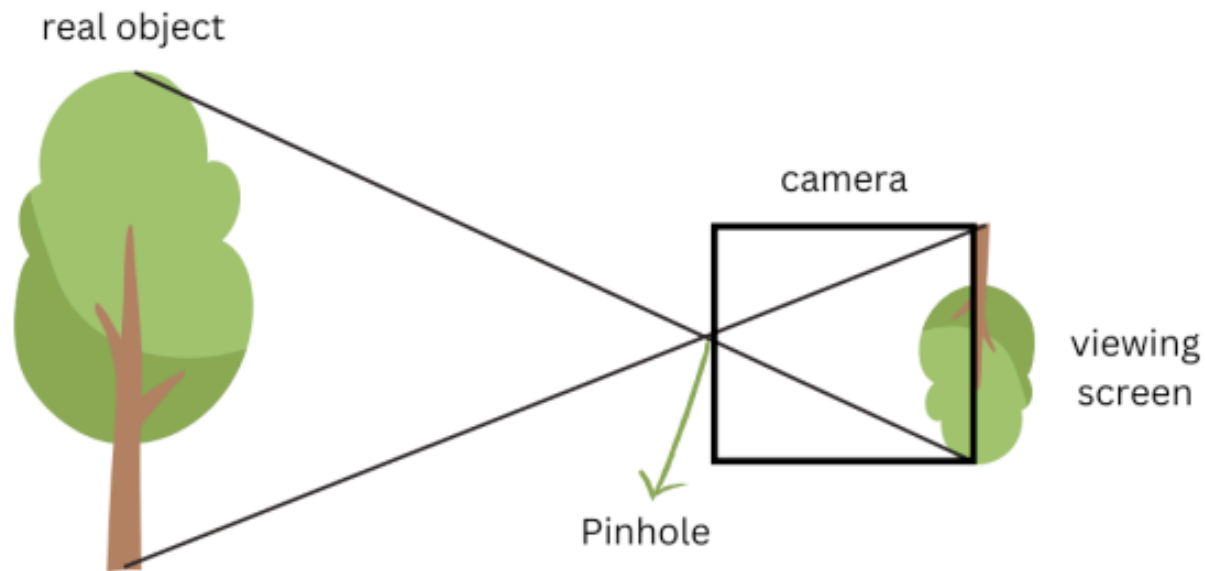
Today, let's spend some time on **sensing**.

A Brief List of Sensors in Use Today

Types of sensors

1. **Cameras**: IR, thermal, radar, Lidar
2. **Microphones**: audible, ultrasound
3. **IMU**: **I**nertial **M**easurement **U**nit
(accelerometer, gyroscope, magnetometer)
4. **Wireless**: GPS, Wifi (WiGig 60GHz, THz), UWB
5. **Assorted**: pressure, humidity, proximity, temperature, chemical traces

How Do Cameras Work?



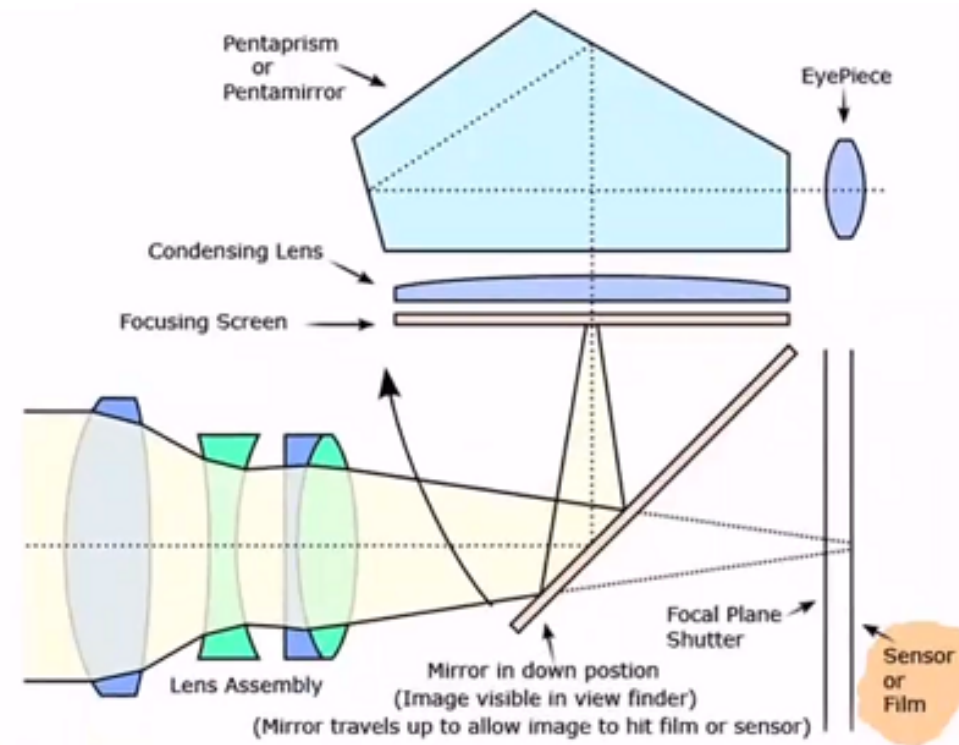
A pinhole camera

Modern SLR Camera Operation

“Single-Lens Reflex” (SLR) camera

The mirror moves to enable the user to “see” what image will be captured on the sensor/film.

Today, light on the sensors produces electrical current, which is recorded.



Arrays of Sensors Have Replaced Film

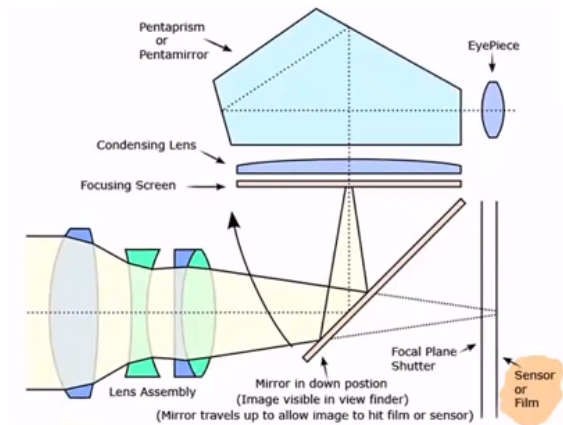
Sensors are tiny today:
single microns (10^{-6} meters).

Each dimension has thousands of pixels (square to obtain several Megapixels).

So an entire array is a few millimeters on a side.

Lenses focus outside image down to a few millimeters.

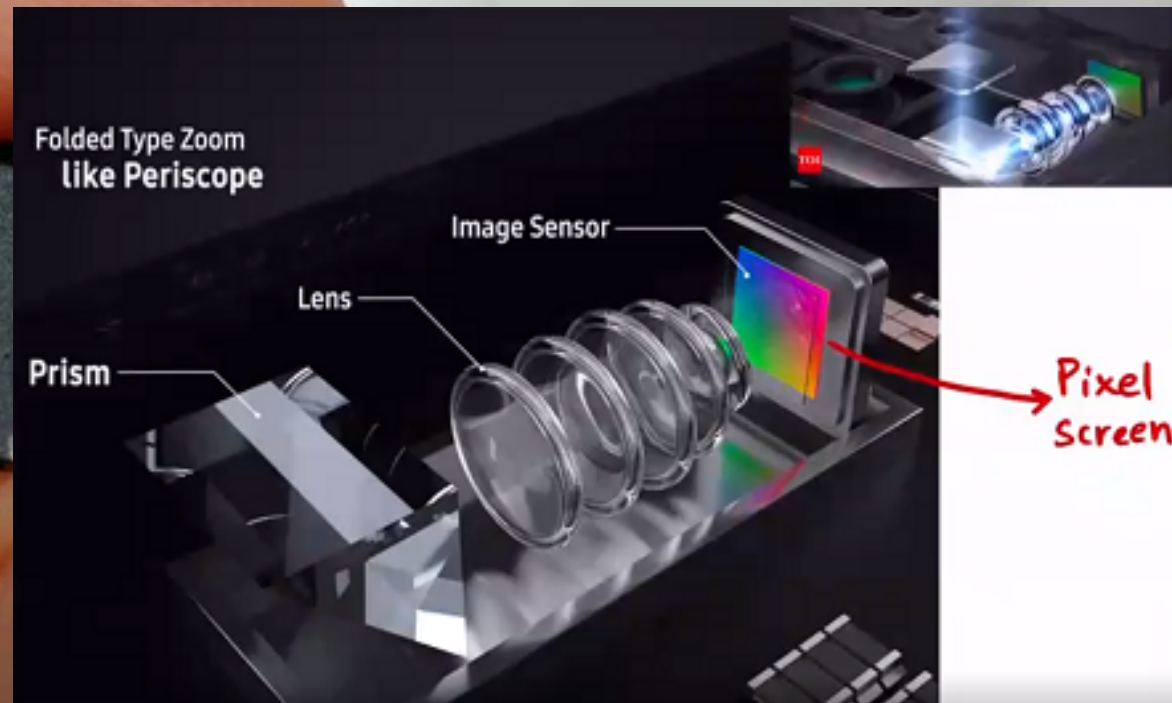
(Larger sensors capture more light more quickly, and are used in more expensive cameras.)



Smartphone Cameras Use a Prism for Compactness

In a smartphone camera, the light is first reflected by a prism, then passed into a set of lenses, and finally focused on the sensor array.

The image seen by the sensor array is reproduced on the phone screen (rather than using a separate viewfinder).



Terminology You Should Know from These Slides

- sense
- compute
- communicate
- actuate
- sense-compute-communicate-actuate (SCCA) loop
- sensors
- SLAM: Simultaneous Localization and Mapping
- pin-hole camera
- smart-phone camera

Concepts You Should Know from These Slides

- how the sense-compute-communicate-actuate (SCCA) loop operates to support “smart” machines
- relationship of the SCCA loop elements to humans
- examples of SCCA loop used in technologies
- examples of types of sensors
- basic operation of cameras and light sensor arrays