Robot Sensing

SS-3406 Introduction to Robotics

RECAP

Summary of Prev Lecture

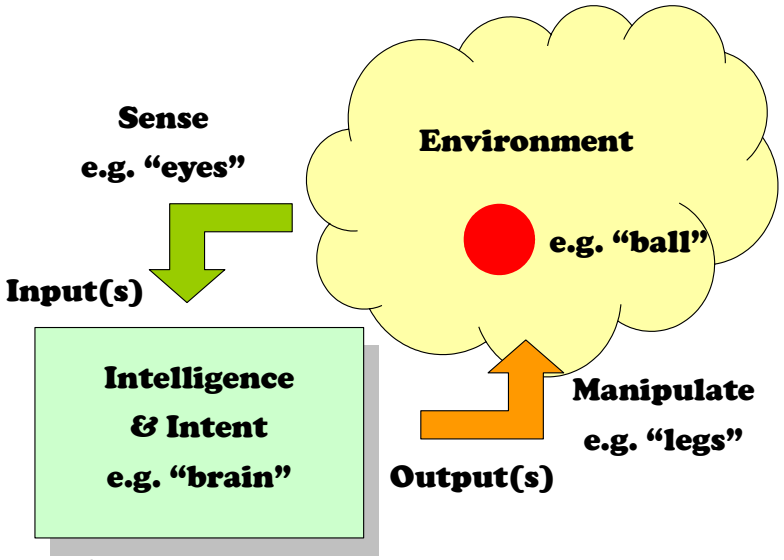
- Applications of robotic technologies.
- Appreciation of robots – it will come big.
- Definition. Well, it is still ambiguous …
- Properties of robots.
- Fields of Study.
- Robotics: include many fields from science to art.
- Types of Robots: modes of operation, application, fields of operation, etc.
- Components of robots.

Today's Menu

- Robot States
  - Internal, External
  - Observability
  - State Space
  - Sensor Space
- Sensors
  - Sensing & Perception
  - Types of Sensors
  - Challenges in Sensing
  - Sensor Characteristics
  - Some Common Sensors

Properties of Robots

- Robots will usually have the following properties:
  - Can **sense** its environment, i.e. have inputs
  - Can **manipulate** things in its environment, i.e. have outputs
  - Have some degree of **intelligent** - programmed by human
  - Appear to have intent or **agency**, i.e. they have their function

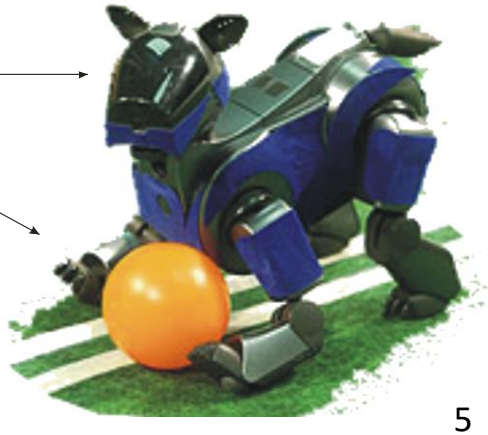


"Brain" for the intelligence
"Intent" to win the game

"Eyes" to sense the ball

"Legs" to manipulate the ball

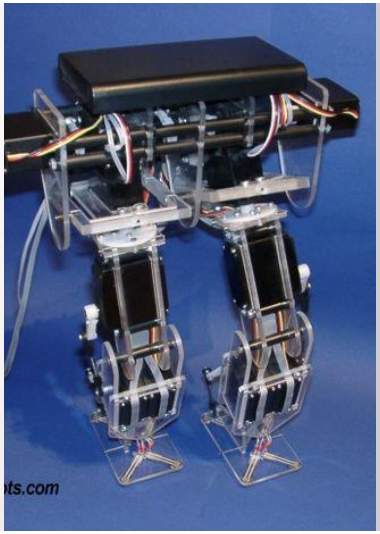
Human made!

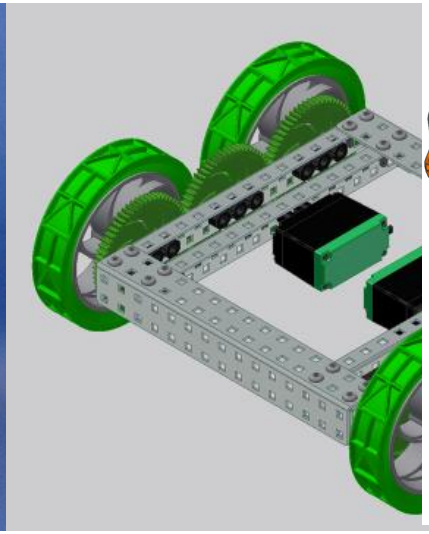


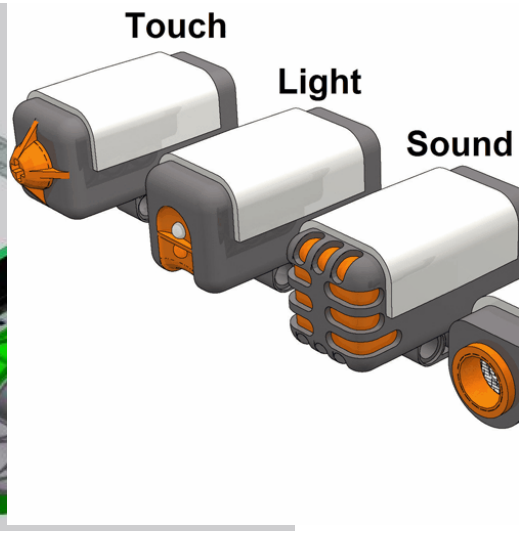
KeepOn

Components of Robots

- **Controller** (control, intelligence | analogy: brain) – Computing
- **Body** (mechanical construct) – Mechanical
- **Actuators**, **effectors** (mechanism and drive train | analogy: limbs, mouth, skin) – Mechanical, Electronics
- **Sensors** (perception| analogy: eyes, ears, skin) – Electronics, Mechanical
- **Power Source** (battery | analogy: food) – Electronics







Intangible Components

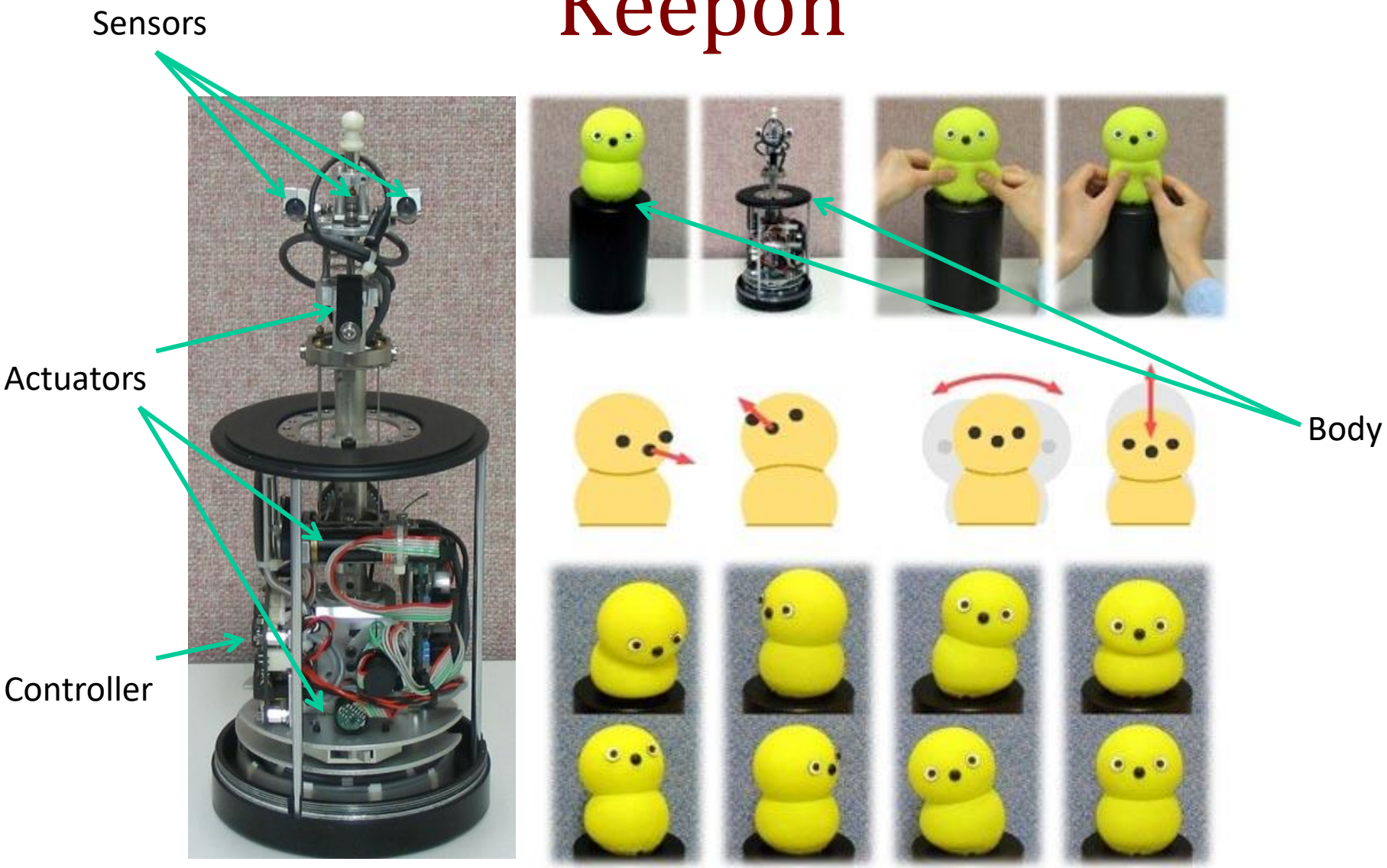
- Arts
  - Creativity in making a robot fun and appealing in its look is an important skill to mention. Robotics can be an art too.
- Behavioral
  - Communication ability
  - Understanding of human emotion while interacting with human
  - Expression of emotion while interacting with human
- Safety

TANGIBLE COMPONENTS

Tangible Components

- Physical body (Body)
  - Provides **embodiment**, so it exists in physical world.
- Sensors (Nerves)
  - **Sense** and **perceive** the environment.
- Effectors and actuators (Limps, lips)
  - Take **action**, so it can interact with elements in physical world.
- Controller (Brain)
  - So it can be **autonomous** (autonomy), or being **controlled** (manual).
- Power Source (Food)

Keepon



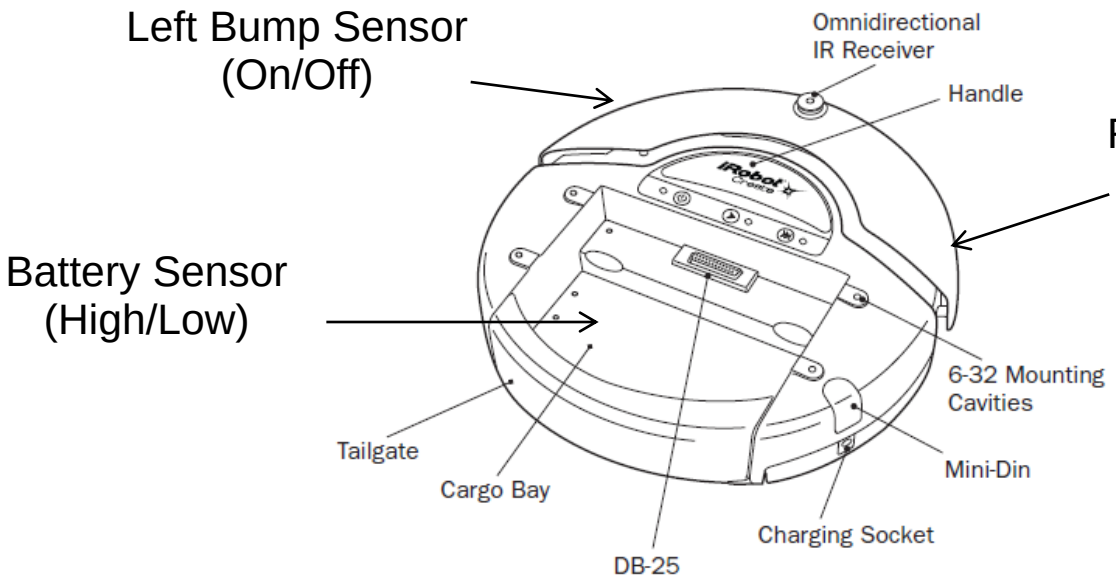
Today's Focus

- Physical body (Body)
  - Provides **embodiment**, so it exists in physical world.
- Sensors (Nerves)
  - **Sense** and **perceive** the environment.
- Effectors and actuators (Limps)
  - Take **action**, so it can interact with elements in physical world.
- Controller (Brain)
  - So it can be **autonomous** (autonomy), or being **controlled** (manual).

ROBOT STATES

States

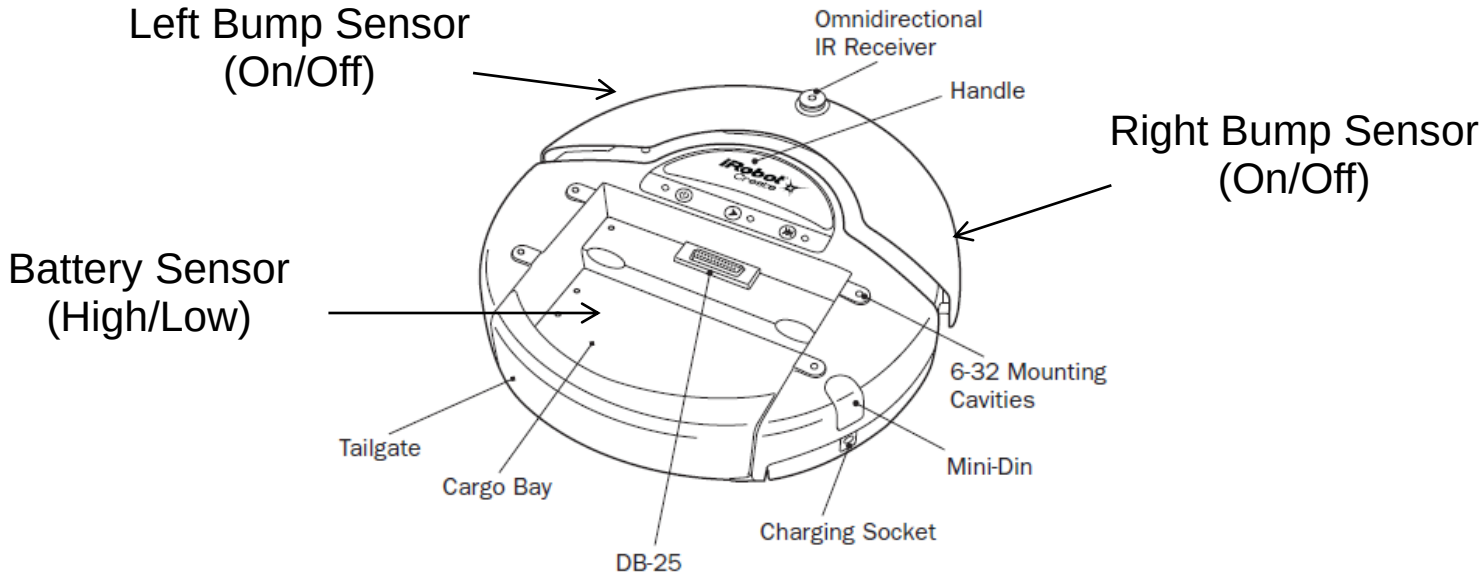
- The **state** of the robot is the **description** of itself at any one time. E.g. The battery is low, the left bumper sensor is on (detected collision), the right bumper sensor is off.



Current State =
Battery Sensor is Low,
Left Bump Sensor is On,
Right Bump Sensor is Off.

Internal, External

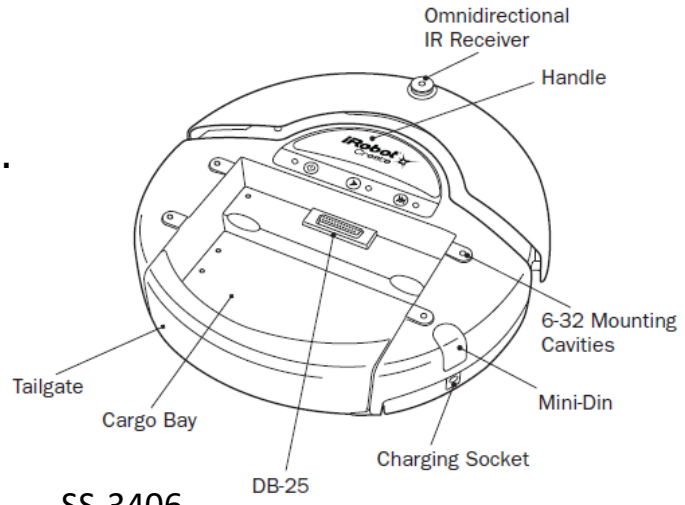
- **Internal state**: state of the robot, e.g. its battery level.
- **External state**: state of its surrounding world, e.g. state from bump sensors.



Observability

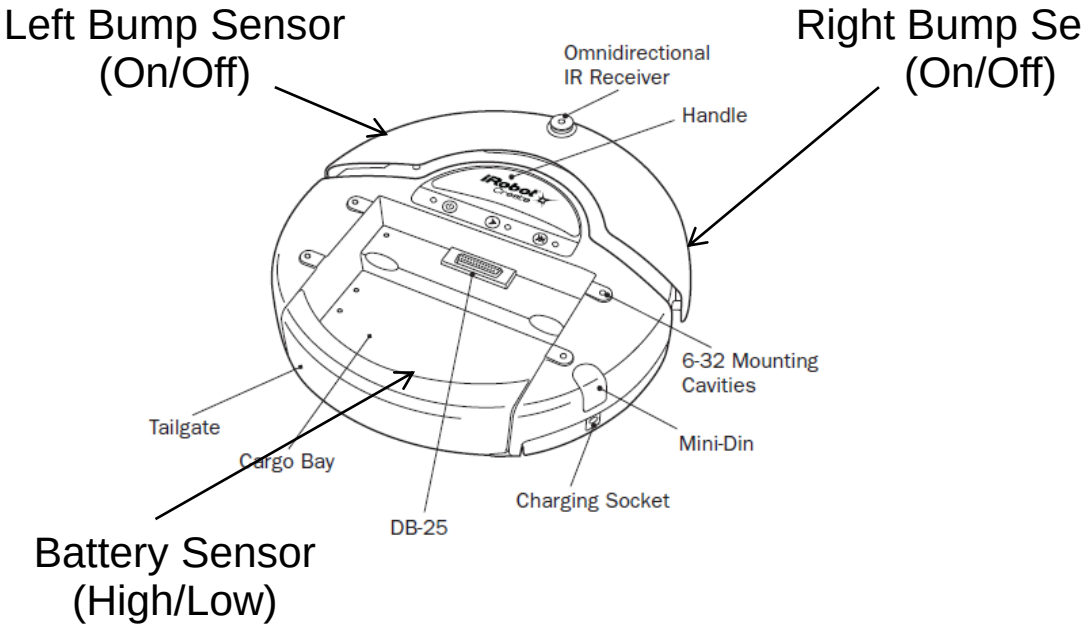
- A robot's state can be:
  - **Observable**: visible, i.e. the robot knows everything about the environment and itself relevant to its operation.
  - **Partially observable**: partially hidden, i.e. some elements in the environment or itself, relevant to its operation, are not visible.
  - **Unobservable**: hidden, i.e. the robot knows nothing about the environment and itself.

Partially observable. E.g. No back sensor when it reverses.



State Space

- **State space**: all possible states of the robot.



State Space

Battery	Left Bump	Right Bump
high	on	on
high	on	off
high	off	on
high	off	on
low	on	on
low	on	off
low	off	on
low	off	on

State = (Internal State) + (External State)
= (Battery Sensor) +
(Left Bump + Right Bump)

State variables:
Battery, left bump, right bump

State size: 8

Sensor Space

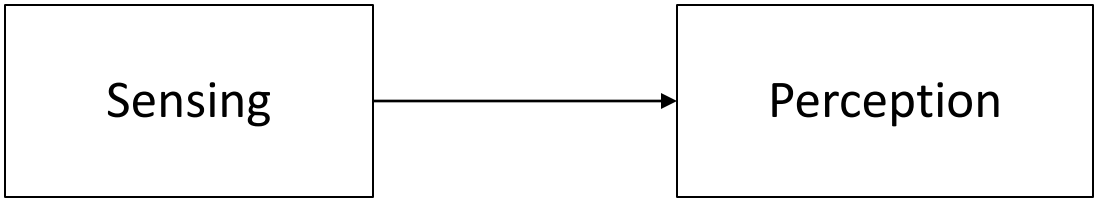
- Not all state variables are from sensors. E.g. A robot knows it is moving forward (forward is a state variable) from the fact it is moving the wheels in the forward direction.
- **Sensor space** or **perceptual space**: state variables from all sensors.

Let’s get on with what are used for finding out the robot’s state …

SENSORS

Sensing and Perception

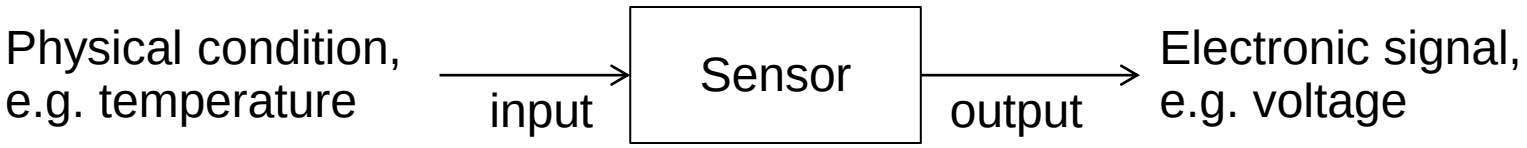
- Sensing receives information about the environment or the world through sensors.
- **Perception** is the awareness about the environment or the world.
- E.g. I hear (sense) walking (stepping) sound from far towards me, I perceive someone is walking to me.



- Sensing allows the robot to know its state.
- Both terms are often treated as synonyms in robotics.

Sensors

- **Sensors** are devices that can sense and measure physical properties of the environment.
  - They convert physical quantities into electronic signals.
  - E.g. Temperature, luminance, resistance to touch, weight, size, etc.
- The key phenomenon is **transduction**.
  - Transduction (engineering) is a process that converts one type of energy to another.
- They deliver low-level information about the environment the robot is working in.
  - Return an incomplete description of the world.



Types by Source

- **Proprioceptive sensors**: senses robot's internal state, i.e. monitor the robot itself.
  - E.g. Positions of the wheels (sensor: encoder), direction the head is facing (sensor: accelerometer).
- **Exteroceptive sensors**: senses robot's external state, i.e. monitor the environment.
  - E.g. Light levels (sensor: light), distances to object (sensor: ultrasonic), sound (sensor: microphone).
- Proprioceptive sensors and exteroceptive sensors together constitute the **perceptual system** of a robot.

More Ways to Classify

- Active versus Passive
  - **Passive**: does not require “power supply”. Has detector only, e.g. light sensor.
  - **Active**: require “power supply”. Has detector and emitter, e.g. radar.
- Classification by **functions**.
  - E.g. Vision sensors, audio sensors, touch (tactile) sensors, range (distance) sensors.
- Classification by modes of **operation**.
  - E.g. Contact versus non-contact.

Challenges in Sensing

- Sensors give low-level information, which need to be **made sense of**.
  - **Low-level** information: right sensor is on, left sensor is off.
  - **High-level** information: there is obstacle at the right side.
- **Uncertainty** in sensor's information.
  - Sensor **noise** and **errors**, e.g. imperfection in manufacturing.
  - Sensor **limitations**, e.g. limited field of view.

Some Sensors and What they Sense

Sensor	Physical Property
Switch	Contact
Ultrasound, radar, infra red	Distance
Photocells, cameras	Light level
Microphones	Sound level
Encoders, potentiometers	Rotation
Accelerometers, gyroscopes	Acceleration
Compass	Magnetism
Chemical sensors	Smell
Thermal, infra red	Temperature
Inclinometers, gyroscopes	Inclination
Pressure gauges	Pressure
Altimeters	Altitude

Sensor Characteristics - 1

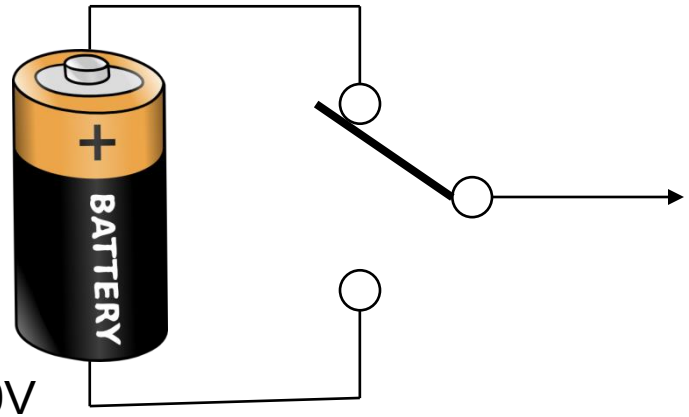
- **Sensitivity**: change in output vs change in input
  - E.g. Light changes from 10lux to 100lux, sensor output changes from 5mV to 50mV, or 10mV to 1000mV.
- **Linearity**: output vs input
  - E.g. 10lux gives 10mV, 100 lux gives 100mV, will 1000lux give 1000mV? (Note: Lux is a unit of measure of light intensity, mV is a unit of measure of electrical voltage)
- Measurement/Dynamic **range**: min to max
  - Difference between min. and max.
- **Response Time**: time required for a change in input to cause a change in the output.
  - E.g. The actual room temperature has raised by 4 deg C, while the sensor reading takes some time to raise by the same amount.

Sensor Characteristics - 2

- **Accuracy**: difference between measured & actual.
  - E.g. Sensor reading says the wall is 20mm away. Is it really 20mm away?
- **Repeatability**: difference between repeated measures.
  - E.g. Given the same distance, will we get same sensor reading if we make the measurement multiple times?
- **Resolution**: smallest observable increment.
  - E.g. Will it detect a change of 10lux or 1lux?
- There are more characteristics.

Electronic Signals (Logic)

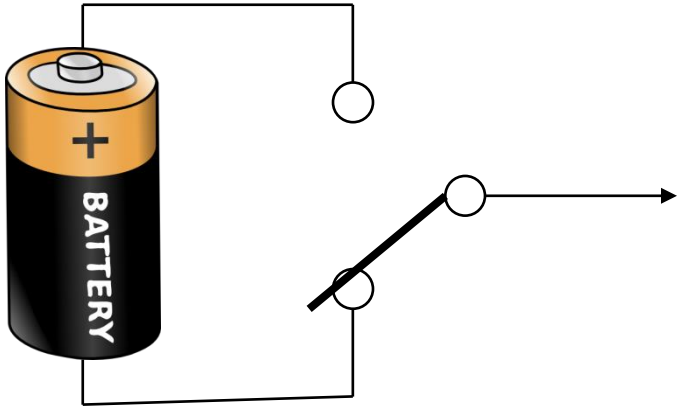
Supply Voltage = e.g. +1.5V



Ground = 0V

+1.5V (Supply Voltage) = Logic One = 1

This voltage is usually used to indicate presence of a sensor output.



0V (No Voltage) = Logic Zero = 0

This voltage is usually used to indicate absense of a sensor output.

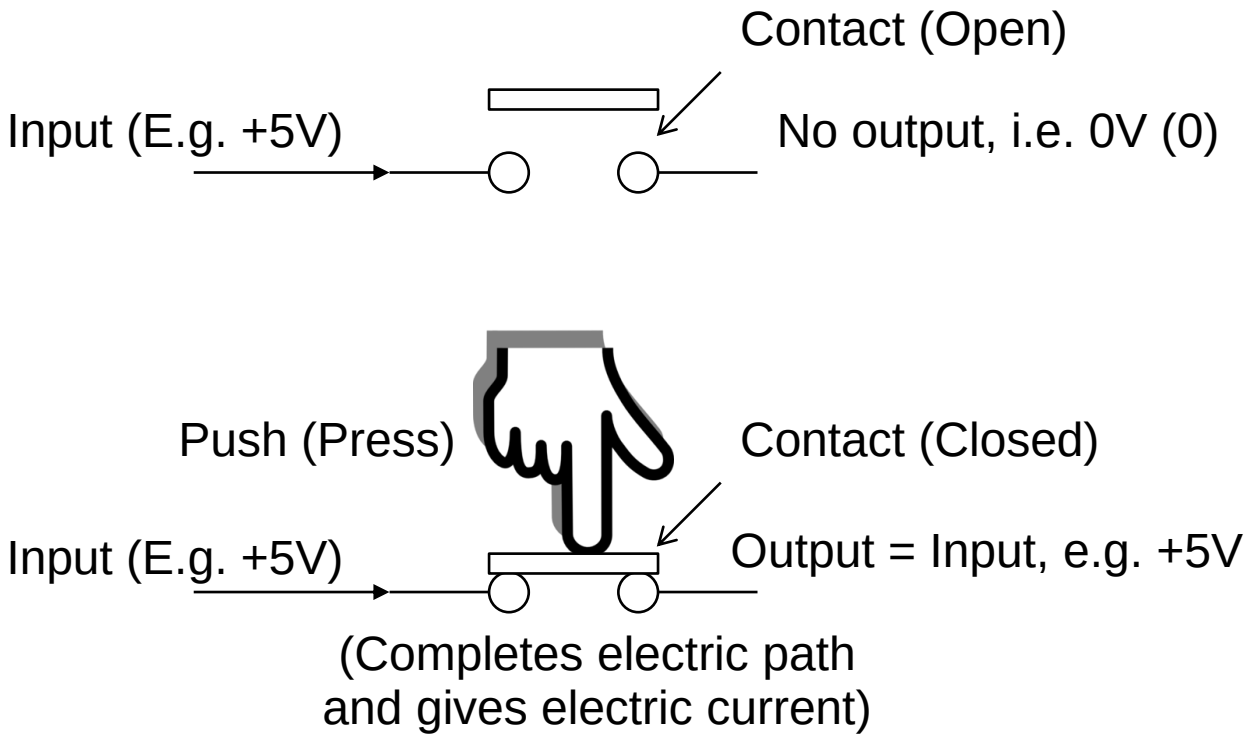
Logic = 0 and 1, No and Yes, False and True

Simplest Sensor: Contact Switch

- Can be used as **tactile** (touch) sensor. E.g. Bump sensor (**detect** obstacle).

Push Button Switch

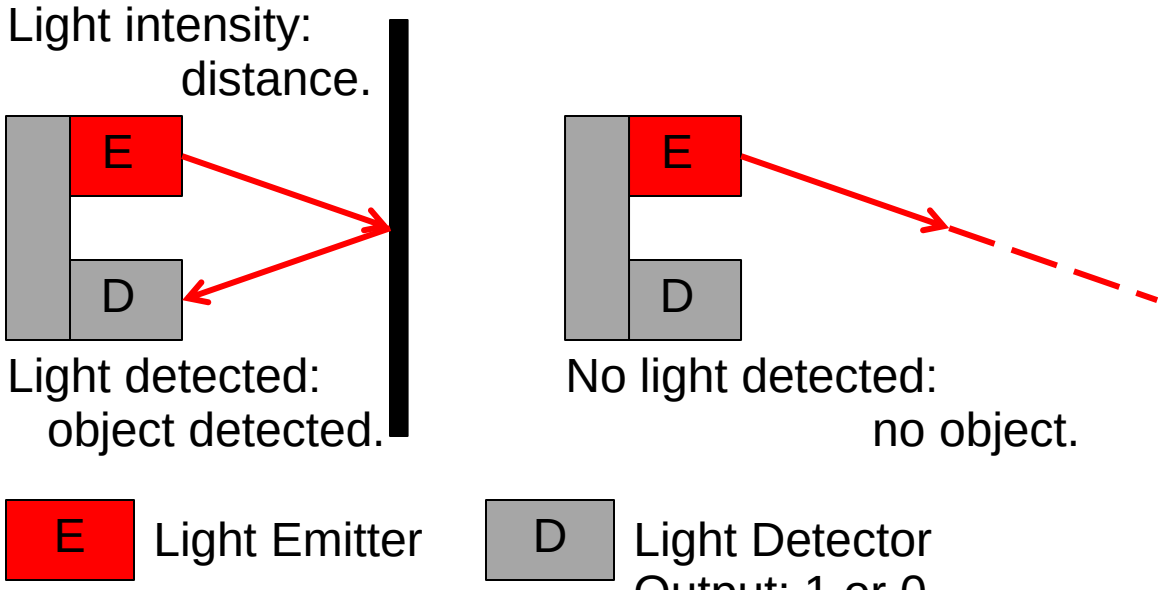
Limit Switch



Reflective Optosensor

- Can be used as range (distance) sensor. E.g. To **avoid** obstacle.
- May be visible or invisible light.
  - Invisible light: infrared (IR).

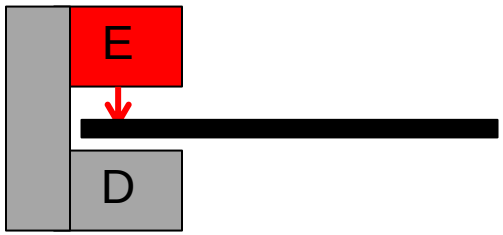
IR Range Sensor



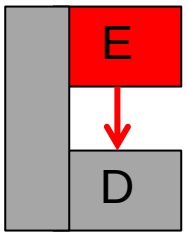
Break Beam Optosensor

- Can be used to sense "**presence**" of object. E.g. Has the door reached its locked position?

IR Opto Sensor



No light detected:
object detected.



Light detected:
no object.

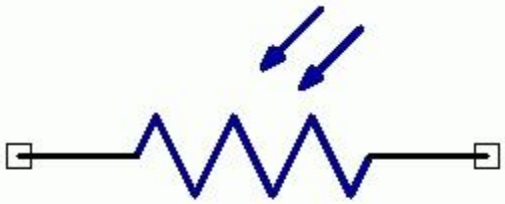
E Light Emitter

D Light Detector
Output: 1 or 0

Light Sensor

- Also called **photocell**.
  - Changes its electrical **resistance** with the amount of light falling on it.

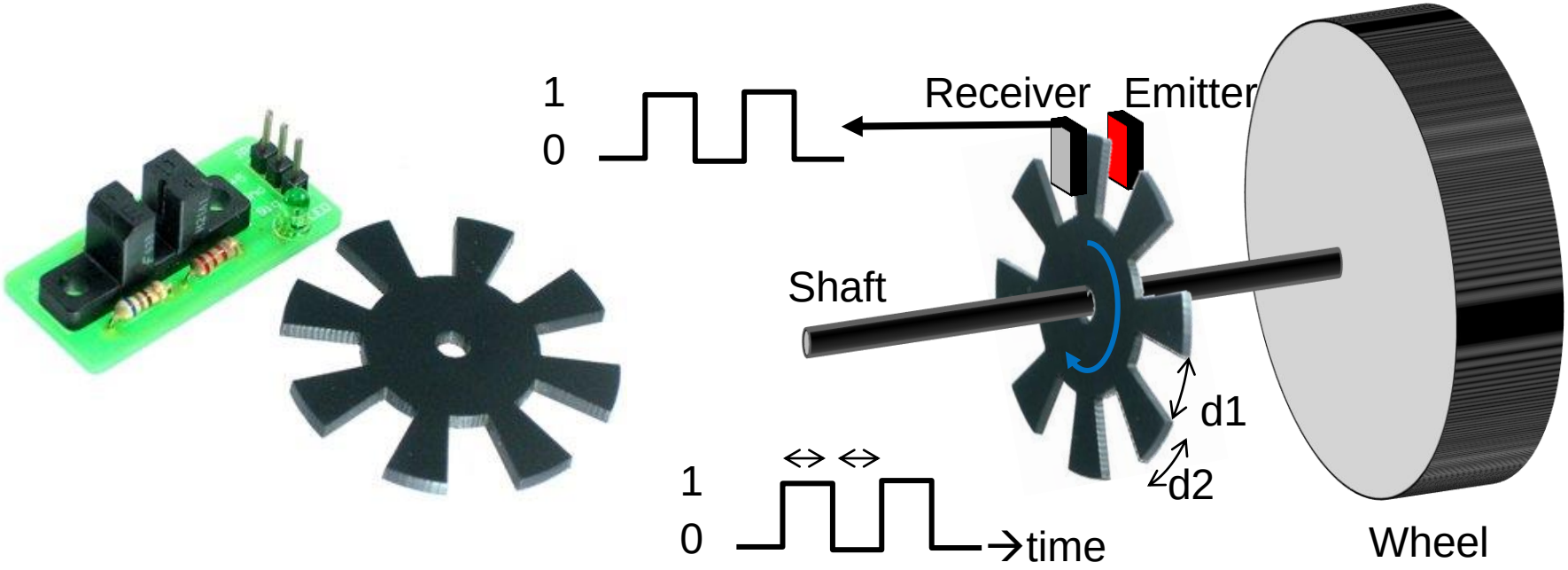
Photocell



Changes in resistance cause changes in voltage and current, hence change the output current and voltage.

Optical Encoder

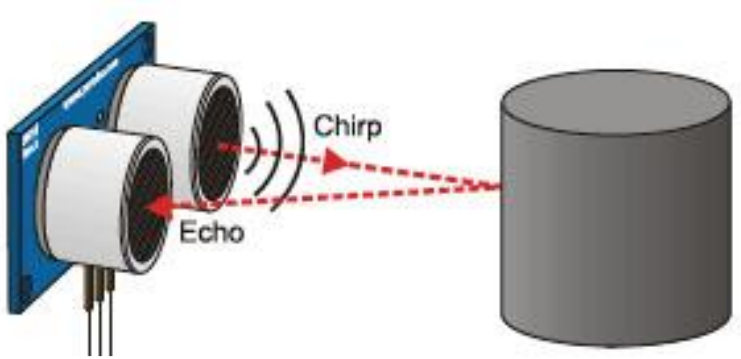
- It **measures** and **counts** the output of break beam optosensor to determine **distance** travelled and the **speed**.



Sonar Sensor (Ultrasonic, Ping)

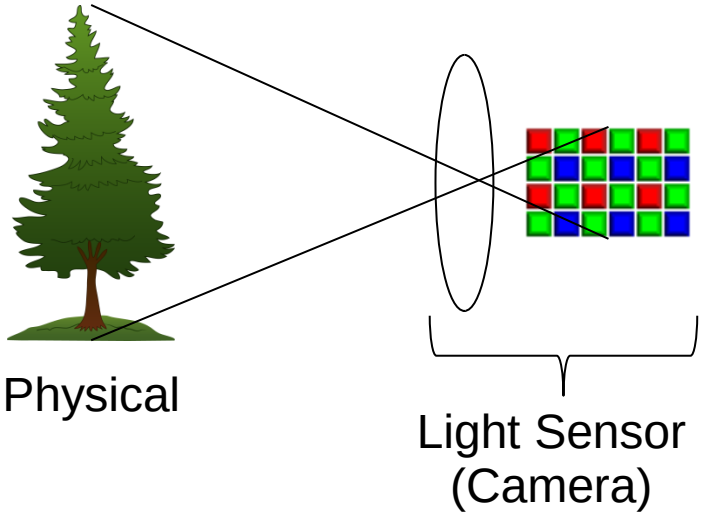
- Used as **range** (distance) sensor.
- Based on **reflection** (echo): sound emitter and detector.
  - Compute distance based on time to receive reflection – knowing the speed of sound.

Ping Sensor

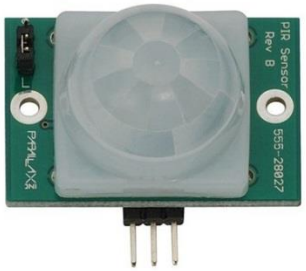


Vision Sensor

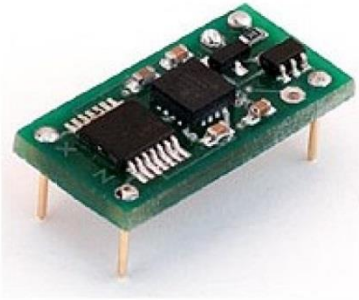
- Often called **camera**.
  - The output of a vision sensor is an **image**.
  - Depending on the **sensor type**, the image may be gray scale, color or in other forms.



More Sensors ...



Motion Sensor



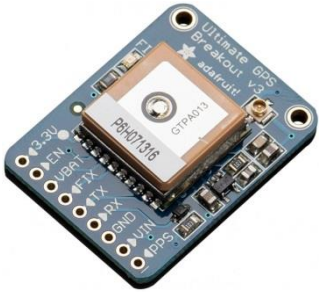
Accelerometer

Laser Range Finder

Camera

Microphone

Thermal Sensor



GPS Sensor

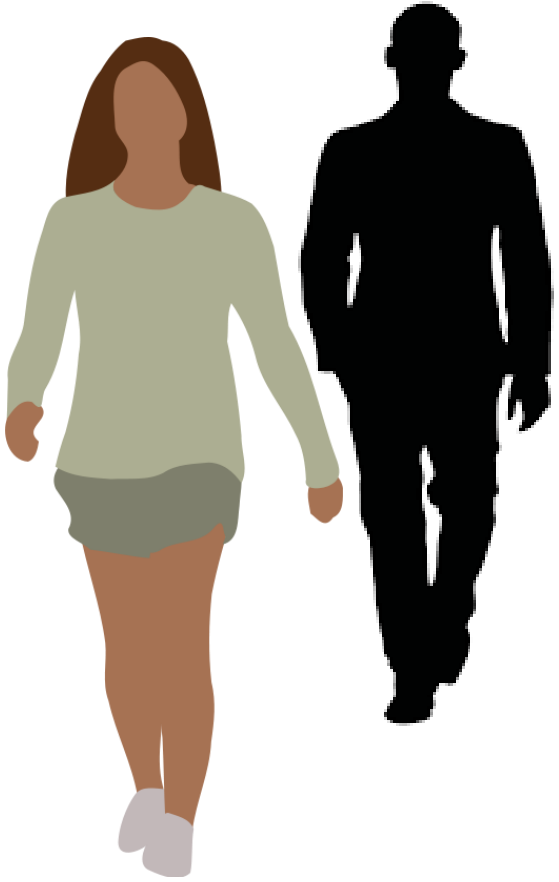
Compass

Selection of Sensors

- What do you want to sense? E.g. door is closed.
- What are the options you have? E.g. contact.
- What are the specifications? E.g. amount of force to operate the switch, size.
  - Knowledge of the specification (limitations and characteristics) of the sensors being used is useful to effectively use them.
- What are the prices?
- Which one fit the purpose? E.g. size within constrained space.

Sensors on My Keepon?

What will you use to detect human?



Reading List

- Keepon: A Playful Robot for Research, Therapy, and Entertainment by Hideki Kozima, et. al.: https://riweb-backend.ri.cmu.edu/pub_files/2009/1/fulltext.pdf
- Servo Magazine Then and Now article on Robot Sensors by Tom Carroll: http://www.robotshop.com/media/files/PDF/servo-magazine-then-now-0707.pdf

To Do List

- List the sensors on the iRobot Create.
  - Do research.
- What sensors do you think can be used to detect the presence of a cat?
- You found an optical encoder that has an inner diameter (shaft hole) of 3mm. Can this optical encoder be used on a motor with 6mm shaft?

Summary

- Robot **states**: **internal** (robot condition) and **external** (environment).
  - **State space**: all possible states of a robot. Not all are observable.
  - **Sensor space** = **perceptual space**: states that can be determined from all the sensors.
- Sensing leads to **perception**.
  - E.g. The Dr sense the heat from a patient's body and perceived that the patient may have a fever.
- **Proprioceptive** sensors for **internal** states, **exteroceptive** sensors for **external** state.
- Some commonly used sensors: contact switch, optosensors, light sensor, encoder, sonar, vision and more.
- Selection of sensors: purpose, options, specifications (limitations and characteristics), prices --> fit for purpose.

References

- The Robotic Primer by Maja J Mataric
- Introduction to Robotics and Intelligent Systems by Ioannis Rekleitis of University of South Carolina.