Fuzzy Logic

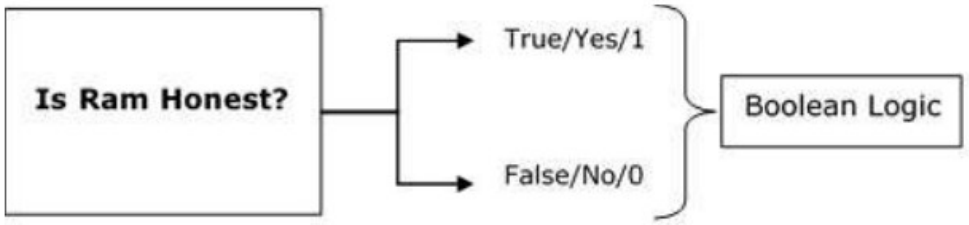
Fuzzy logic idea is similar to the human being's feeling and inference process. The word ***fuzzy*** refers to things which are **not clear** or are **vague**. Any event, process, or function that is changing continuously cannot always be defined as either **true** or **false**, which means that we need to define such activities in a Fuzzy manner.

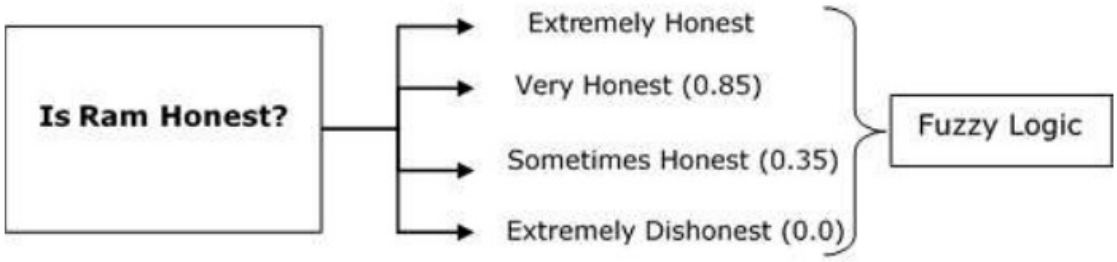
What is Fuzzy Logic?

Fuzzy Logic resembles the **human decision-making** methodology. It deals with vague and imprecise information.

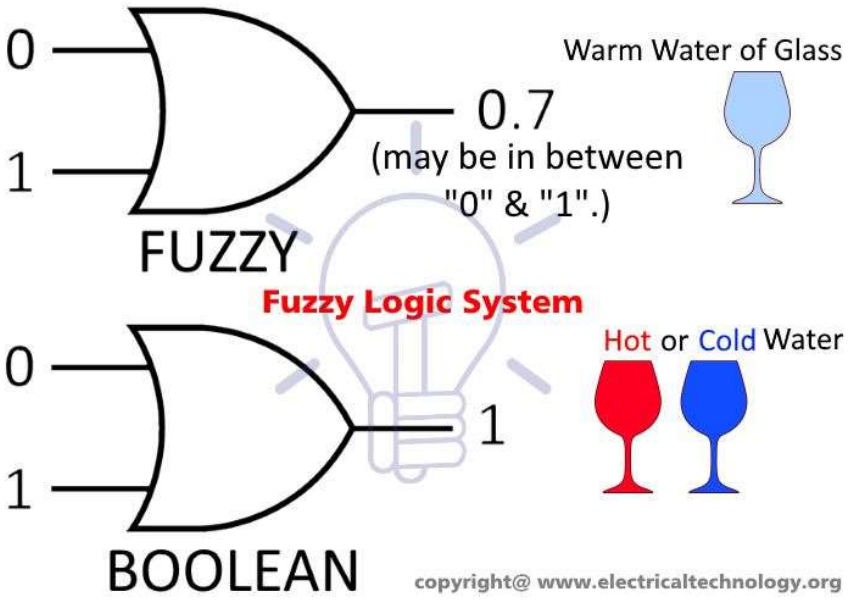
Example:

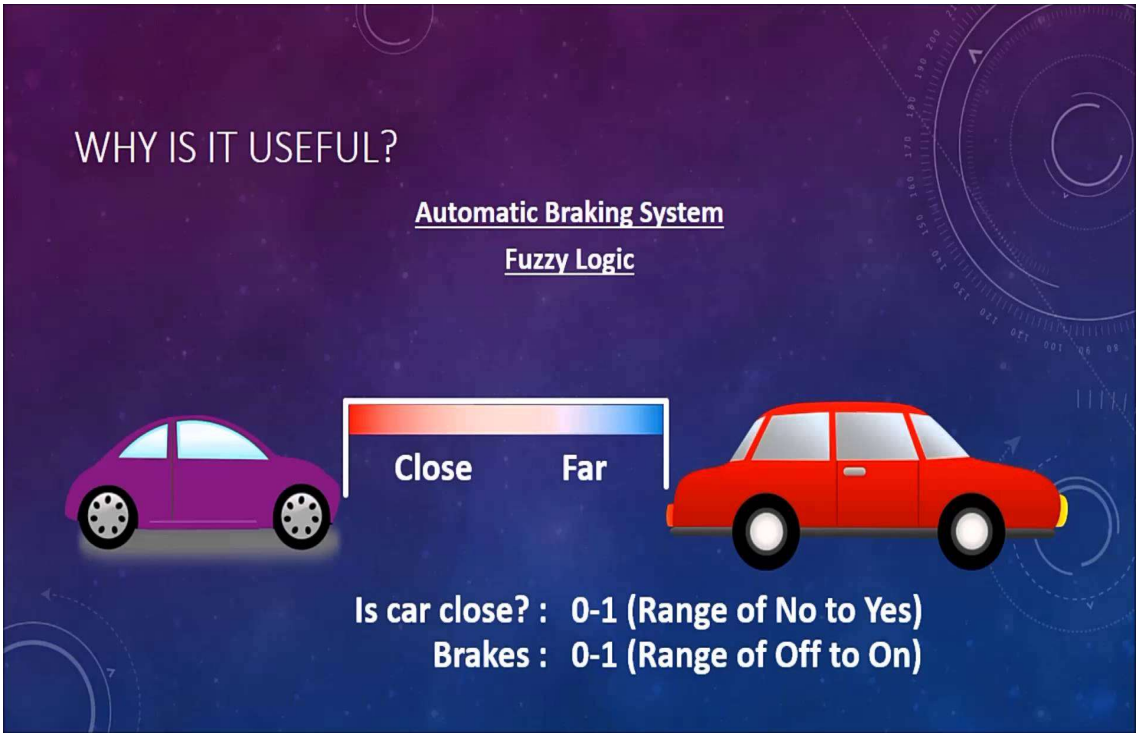
Take a look at the following diagram. It shows that in fuzzy systems, the values are indicated by a number in the range from **0 to 1**. Here **1.0 represents absolute truth and 0.0 represents absolute falseness**. The number which indicates the value in fuzzy systems is called the **truth value**.

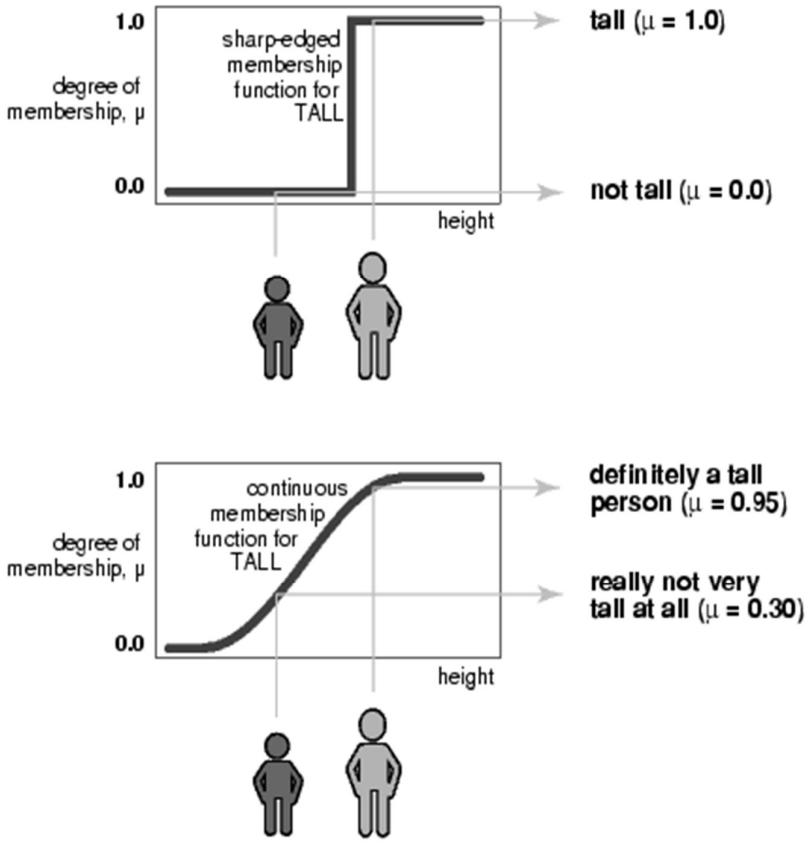




In other words, we can say that **fuzzy logic** is **not logic** that is **fuzzy**, but **logic** that is used to describe **fuzziness**. There can be numerous other examples like this with the help of which we can understand the concept of fuzzy logic.


0
1
0.7
(may be in between "0" & "1".)
FUZZY
Warm Water of Glass
Fuzzy Logic System
0
1
1
BOOLEAN
Hot or Cold Water
copyright@ www.electricaltechnology.org


WHY IS IT USEFUL?
Automatic Braking System
Fuzzy Logic
Close
Far
Is car close? : 0-1 (Range of No to Yes)
Brakes : 0-1 (Range of Off to On)



Introduction

- Fuzzy concepts first introduced by **Zadeh** in the 1960s and 70s

- Traditional computational logic and set theory is all about

  - true or false
  - zero or one
  - in or out (in terms of set membership)
  - black or white (no grey)

- Not the case with fuzzy logic.

Basic Concepts

- Approximation ("granulation")
    - A colour can be described precisely using **RGB** values, or it can be approximately described as "red", "blue", etc.
- Degree ("graduation")
    - Two different colours may both be described as "red", but one is considered to be more red than the other
- Fuzzy logic attempts to reflect the human way of thinking

Terminology

Fuzzy set

A set X in which each element y has a grade of membership f(y) in the range **0 to 1**, i.e. set membership may be partial e.g. if cold is a fuzzy set, exact temperature values might be mapped to the fuzzy

set as follows:

15 degrees → 0.2 (slightly cold)

10 degrees → 0.5 (quite cold)

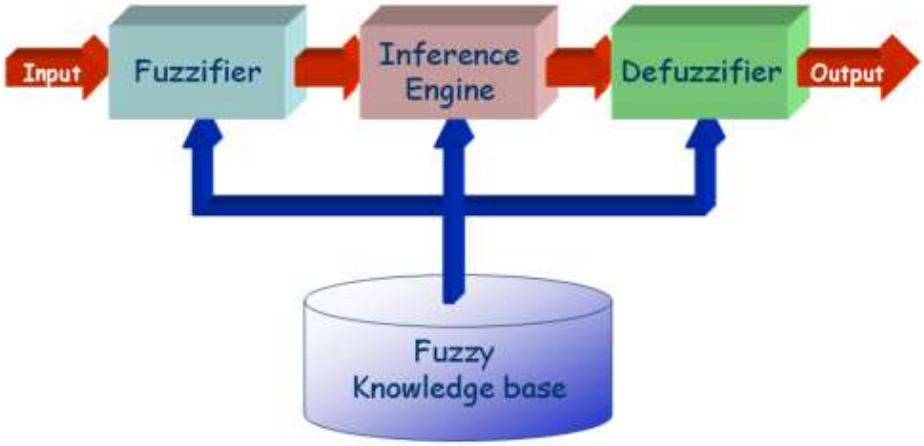
0 degrees → 1 (totally cold)

To implement fuzzy logic technique to a real application requires the following three steps:

1. **Fuzzification** – convert classical data or **crisp data** into **fuzzy data** or **Membership Functions** (MFs)

2. **Fuzzy Inference Process** – combine membership functions with the control rules to derive the fuzzy output

3. **Defuzzification** – use different methods to calculate each associated output and put them into a table: the lookup table. Pick up the output from the lookup table based on the current input during an application



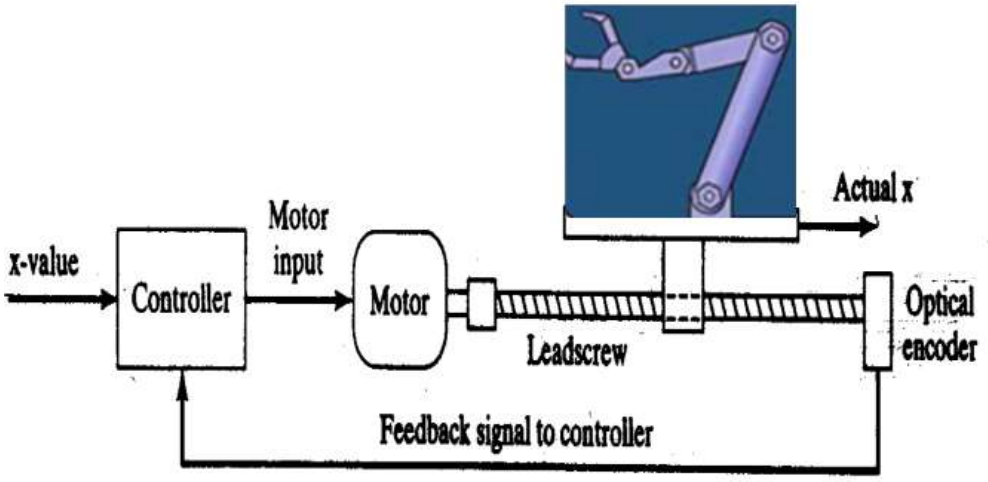
For example, here are some rules of conduct that a driver follows, assuming that he does not want to lose his driver's licence:

If the light is red...	if my speed is high...	and if the light is close...	then I brake hard.
If the light is red...	if my speed is low...	and if the light is far...	then I maintain my speed.
If the light is orange...	if my speed is average...	and if the light is far...	then I brake gently.
If the light is green...	if my speed is low...	and if the light is close...	then I accelerate.

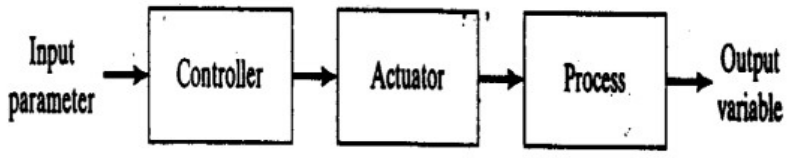
Sensors and Actuators

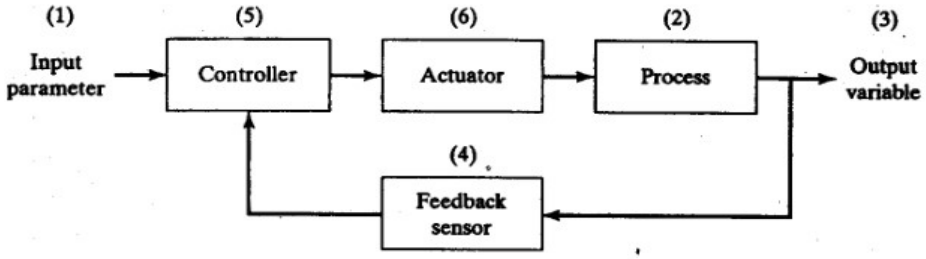
Sub-systems in robot control

- Controller
- Actuator
- Sensor
- Process/model/robot



Open loop and closed loop:





An **open-loop control** system utilizes a controller or control actuator to obtain the **desired response,** as shown in Figure. The open-loop control system utilizes an actuating device to control the process directly without using device. An example of an open-loop control system is an **electric toaster**.

A **closed-loop control system** (as shown in above Figure) utilizes an additional measure of the **actual output** to compare the **actual output** with the **desired output response**. The measure of the output is called the **feedback signal**. A **feedback control system** is a **control system that tends to maintain a relationship of one system variable to another by comparing functions of these variables and using the difference as a means of control**.

Sensors are devices that can sense and measure physical properties of the environment. Allow a robot to interact with its environment in a flexible, and intelligent manner

- e.g. temperature, luminance, resistance to touch, weight and size.
- 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 work in

Types of sensor

- General classification: active versus passive
- Active: emit energy in environment
- Passive: passively receive energy, e.g. light for camera
- Example: stereo vision versus range finder.

Specific examples

Tactile, close-range proximity, infrared, Sonar, laser (various types), radar, compasses, gyroscopes, Force, GPS and finally vision.

General Classification of Sensors

- Internal sensors: Provide position, velocity, and acceleration as a continuous stream of feedback signals that possess an integral part of the control loop
- External sensors: Provide information about the environment and the objects therein (for collision and avoidance). Also, don' t come with the basic package. Can be bought and installed as optional sensors

Sensor Characteristics

- **Dynamic range**: Minimum and maximum values of the input signal for which the sensor responds
- **Response**: Sensor should respond to the stimuli almost instantaneously
- **Sensitivity**: The change in sensor output for a unit change in input
- **Linearity**: Whether the sensor maintains same sensitivity within the entire dynamic range

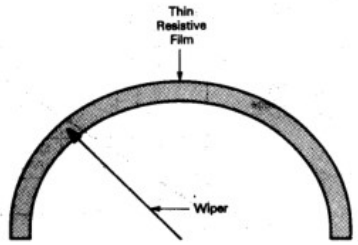
Other considerations

- Sensor should not disturb the physical quantity it measures
- Sensor should be suitable for the environment it is exposed
- Sensor should be isolated from noise, and protected from physical damages
- Size, cost, and ease of operation

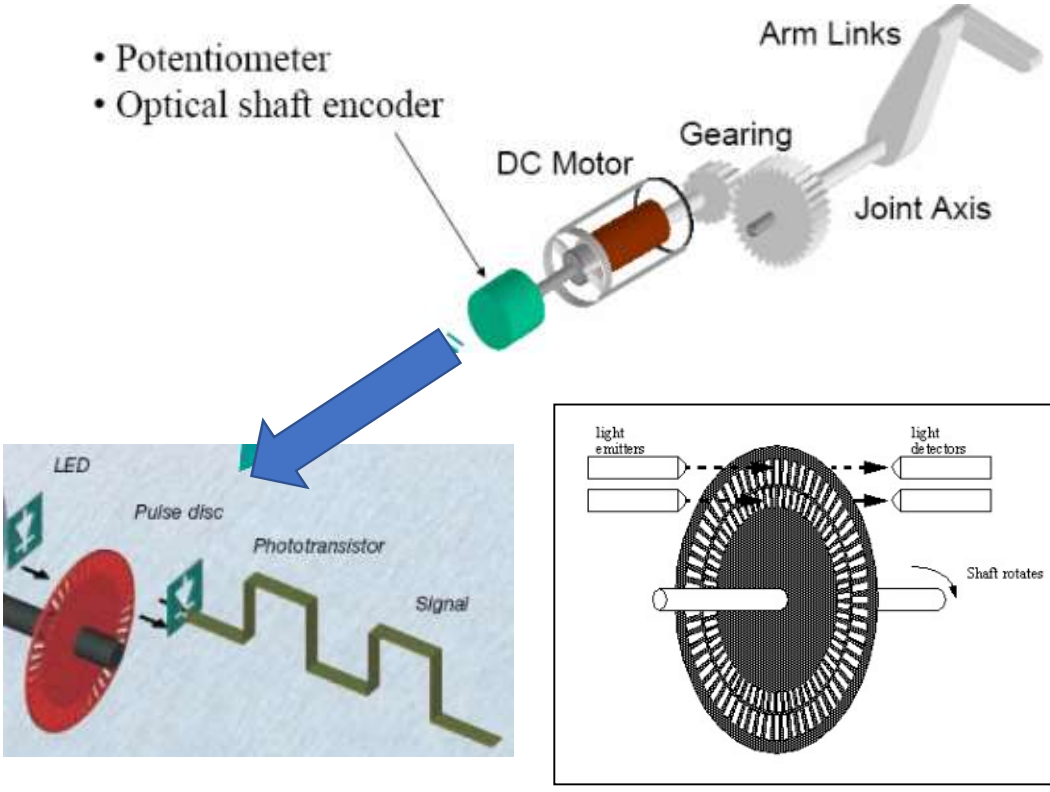
Sensors used for closed loop

- position control: Internal sensors (Position and Velocity).
- Sensors for interaction with the environment: External sensors (Touch, Force, Pressure and Vision). For example: on/off switches, ultrasonic, force sensor and piezo sensor

Position Sensor: Potentiometer



Position sensor: Incremental Encoder



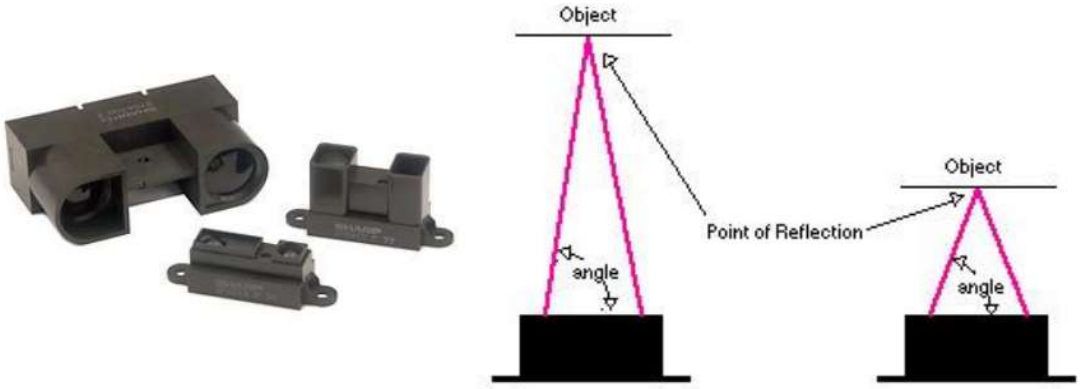
Contact, or Tactile, Sensors

Contact sensor operation is based on transducers. Almost all contact sensors measure one of **three different physical quantities**: touch/force, proximity, and slip. **Touch** includes whether something is touching, the pressure of a touch. and weights and forces, example: Limit switches, On /Off switches. **Proximity** sensors measure the nearness of objects and displacements of the robot or

target. **Slip** refers to the motion of an object sliding out of a mechanical hand or gripper.

Infrared Sensors

Measures the return angle of the **infrared beam**.



If the IR signal is detected, it is safe to assume that an object is present

- However, the absence of reflected IR does not mean that no object is present!. certain dark colours (black) are almost invisible to IR

– IR sensors are not absolutely safe for object detection

- In realistic situations (different colours & types of objects) there is no accurate distance information

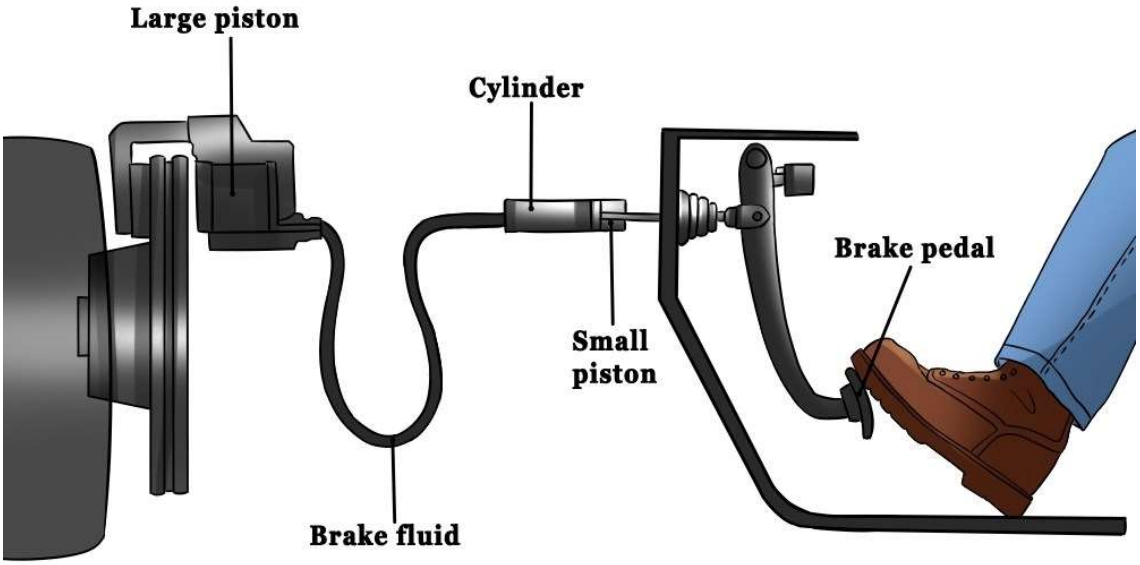
– it is best to avoid objects as soon as possible.

- IR are short range (typically maximum range 50 to 100 cm)

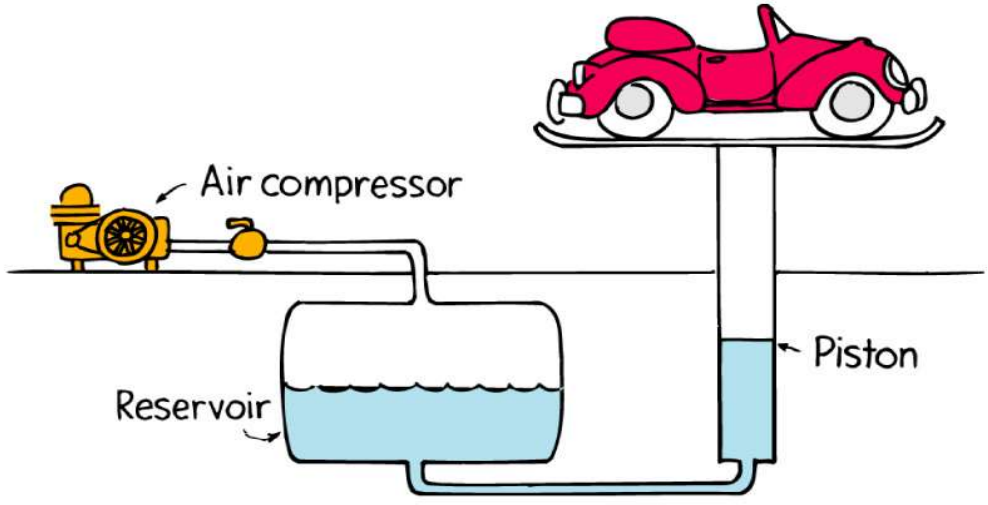
Actuators

Electrical : stepper motors, DC servo motors

Pneumatic : air pressure

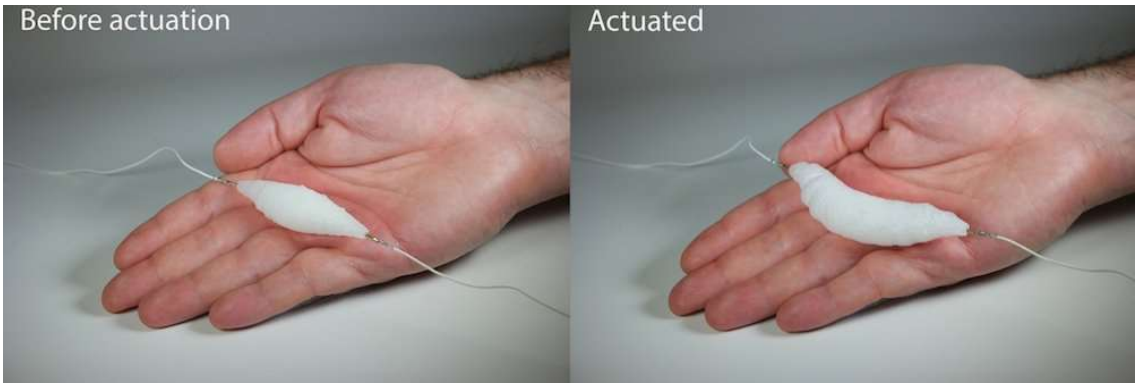


Hydraulic: fluid pressure (oil pressure).



Advanced actuators : ultrasonic motors,

artificial muscles, molecular motors.


Before actuation
Actuated