IIT KHARAGPUR

NPTEL ONLINE
CERTIFICATION COURSES

Sensing

Definition

- A sensor detects (senses) changes in the ambient conditions or in the state of another device or a system, and forwards or processes this information in a certain manner [1].

"A device which detects or measures a physical property and records, indicates, or otherwise responds to it" [2].

- Oxford Dictionary

References:

1. http://www.businessdictionary.com/definition/sensor.html
2. https://en.oxforddictionaries.com/definition/sensor

Sensors

- ✔ They perform some input functions by sensing or feeling the physical changes in characteristics of a system in response to a stimuli.
- ✔ For example heat is converted to electrical signals in a temperature sensor, or atmospheric pressure is converted to electrical signals in a barometer.

Transducers

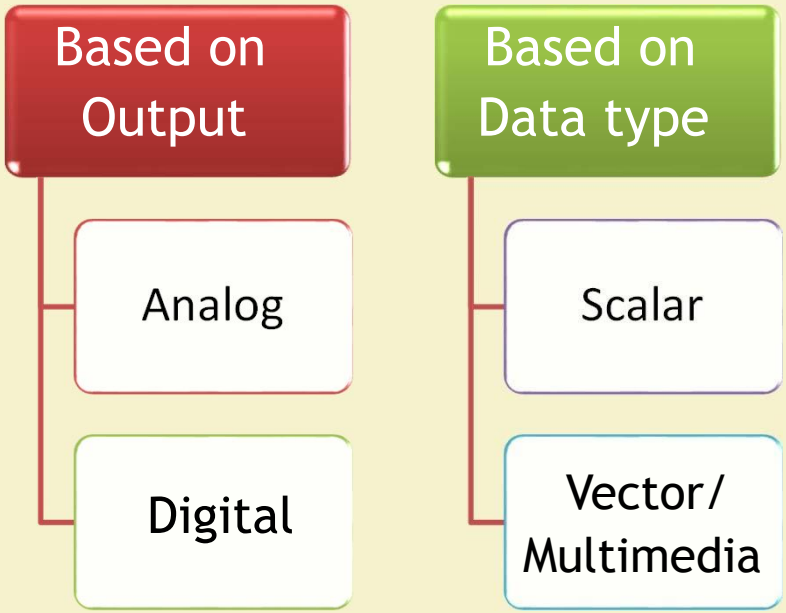
- ✔ Transducers convert or transduce energy of one kind into another.
- ✔ For example, in a sound system, a microphone (input device) converts sound waves into electrical signals for an amplifier to amplify (a process), and a loudspeaker (output device) converts these electrical signals back into sound waves.

Sensor vs. Transducer

- The word “Transducer” is the collective term used for both **Sensors** which can be used to sense a wide range of different energy forms such as movement, electrical signals, radiant energy, thermal or magnetic energy etc., and **Actuators** which can be used to switch voltages or currents [1].

References:
1. http://www.electronics-tutorials.ws/io/io_1.html

Sensor Classes



Analog Sensors

- **Analog Sensors** produce a continuous output signal or voltage which is generally proportional to the quantity being measured.
- Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc. are all analog quantities as they tend to be continuous in nature.
- For example, the temperature of a liquid can be measured using a thermometer or thermocouple (e.g. in geysers) which continuously responds to temperature changes as the liquid is heated up or cooled down.

Digital Sensors

- **Digital Sensors** produce discrete digital output signals or voltages that are a digital representation of the quantity being measured.
- Digital sensors produce a binary output signal in the form of a logic "1" or a logic "0", ("ON" or "OFF").
- Digital signal only produces discrete (non-continuous) values, which may be output as a single "bit" (serial transmission), or by combining the bits to produce a single "byte" output (parallel transmission).

Scalar Sensors

- **Scalar Sensors** produce output signal or voltage which is generally proportional to the magnitude of the quantity being measured.
- Physical quantities such as temperature, color, pressure, strain, etc. are all scalar quantities as only their magnitude is sufficient to convey an information.
- For example, the temperature of a room can be measured using a thermometer or thermocouple, which responds to temperature changes irrespective of the orientation of the sensor or its direction.

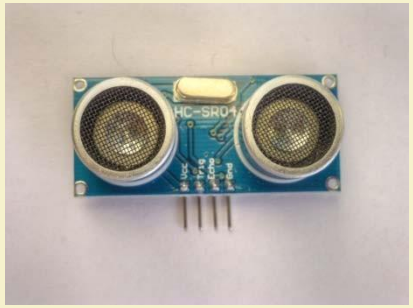
Vector Sensors

- **Vector Sensors** produce output signal or voltage which is generally proportional to the magnitude, direction, as well as the orientation of the quantity being measured.
- Physical quantities such as sound, image, velocity, acceleration, orientation, etc. are all vector quantities, as only their magnitude is not sufficient to convey the complete information.
- For example, the acceleration of a body can be measured using an accelerometer, which gives the components of acceleration of the body with respect to the x,y,z coordinate axes.

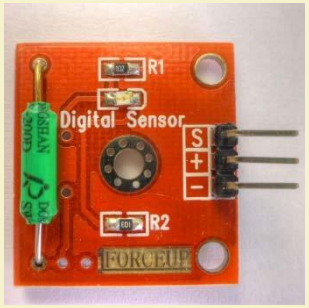
Sensor

Light	• Light Dependent resistor • Photo-diode
Temperature	• Thermocouple • Thermistor
Force	• Strain gauge • Pressure switch
Position	• Potentiometer, Encoders • Opto-coupler
Speed	• Reflective/ Opto-coupler • Doppler effect sensor
Sound	• Carbon Microphone • Piezoelectric Crystal
Chemical	• Liquid Chemical sensor • Gaseous chemical sensor

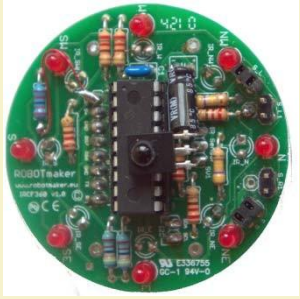
Pressure Sensor
Source: Wikimedia Commons



Ultrasonic Distance Sensor
Source: Wikimedia Commons

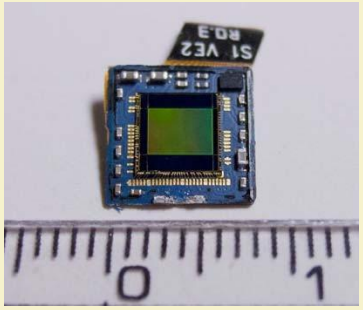


Tilt Sensor
Source: Wikimedia Commons



Infrared Motion Sensor
Source: Wikimedia Commons

Analog Temperature Sensor
Source: Wikimedia Commons



Camera Sensor
Source: Wikimedia Commons

SIK

Name	Image	Type	Function	Notes
Push Button		Digital Input	Switch - Closes or opens circuit	Polarized, needs resistor
Trim potentiometer		Analog Input	Variable resistor	Also called a Trimpot.
Photoresistor		Analog Input	Light Dependent Resistor (LDR)	Resistance varies with light.
Relay		Digital Output	Switch driven by a small signal	Used to control larger voltages
Temp Sensor		Analog Input	Temp Dependent Resistor	
Flex Sensor		Analog Input	Variable resistor	
Soft Trimpot		Analog Input	Variable resistor	Careful of shorts
RGB LED		Dig & Analog Output	16,777,216 different colors	

Steady State Characteristics of Sensors

- ✔ Accuracy
- ✔ Resolution
- ✔ Range
- ✔ Drift
- ✔ Repeatability

Reference:
https://en.wikipedia.org/wiki/Sensor

Sensor Features

- ✔ It is only sensitive to the measured property (e.g., A temperature sensor senses the ambient temperature of a room.)
- ✔ It is insensitive to any other property likely to be encountered in its application (e.g., A temperature sensor does not bother about light or pressure while sensing the temperature.)
- ✔ It does not influence the measured property (e.g., measuring the temperature does not reduce or increase the temperature).

Sensor Resolution

- ✔ The resolution of a sensor is the smallest change it can detect in the quantity that it is measuring.
- ✔ The resolution of a sensor with a digital output is usually the smallest resolution the digital output it is capable of processing.
- ✔ The more is the resolution of a sensor, the more accurate is its precision.
- ✔ A sensor's accuracy does not depend upon its resolution.

Sensorial Deviations

- ✔ Since the range of the output signal is always limited, the output signal will eventually reach a minimum or maximum, when the measured property exceeds the limits. The full scale range of a sensor defines the maximum and minimum values of the measured property.
- ✔ The sensitivity of a sensor under real conditions may differ from the value specified. This is called a **sensitivity error**.
- ✔ If the output signal differs from the correct value by a constant, the sensor has an **offset error** or **bias**.

Reference: https://en.wikipedia.org/wiki/Sensor

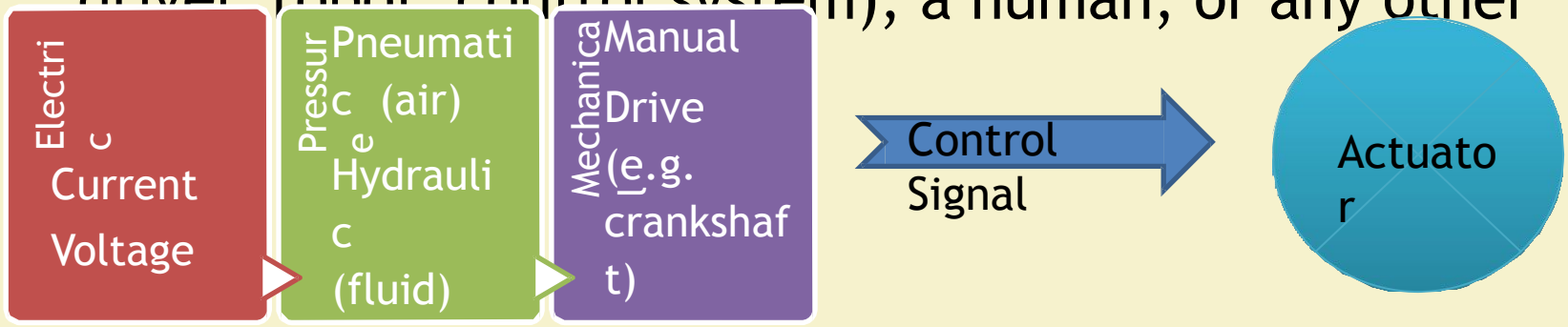
- If the output signal slowly changes independent of the measured property, this is defined as **drift**. Long term drift over months or years is caused by physical changes in the sensor.
- **Noise** is a random deviation of the signal that varies in time.

Reference:
https://en.wikipedia.org/wiki/Sensor

Actuator

- An actuator is a component of a machine or system that moves or controls the mechanism or the system.
- An actuator is the mechanism by which a control system acts upon an environment
- An actuator requires a control signal and a source of energy.

- Upon receiving a control signal is received, the actuator responds by converting the energy into mechanical motion.
- The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), a human, or any other



Actuator Types

Hydraulic
Pneumatic

Electrical

Thermal/ Magnetic

Mechanical

Hydraulic Actuators

- ✔ A hydraulic actuator consists of a cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation.
- ✔ The mechanical motion is converted to linear, rotary or oscillatory motion.
- ✔ Since liquids are nearly impossible to compress, a hydraulic actuator exerts considerable force.
- ✔ The actuator's limited acceleration restricts its usage.

Reference: https://en.wikipedia.org/wiki/Actuator

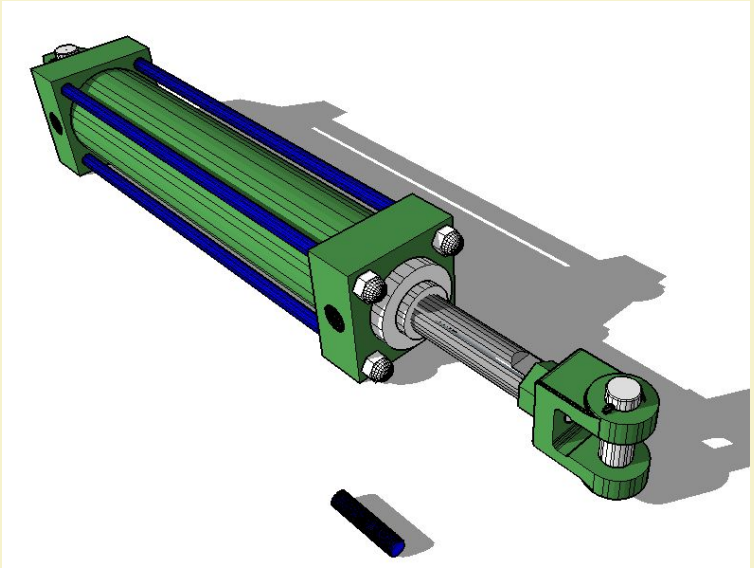


Fig: An oil based hydraulic actuator

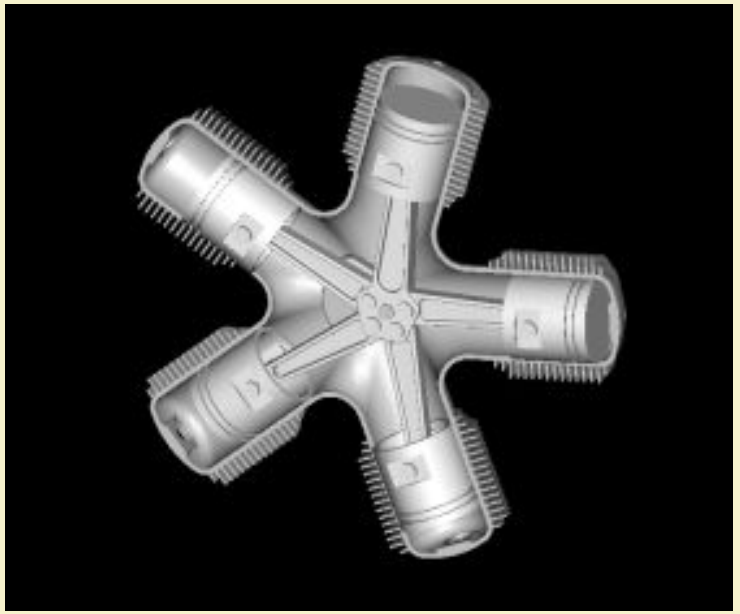


Fig: A radial engine acts as a hydraulic actuator

Source: Wikimedia Commons

File: Radial_engine.gif

Pneumatic Actuators

- ✔ A pneumatic actuator converts energy formed by vacuum or compressed air at high pressure into either linear or rotary motion.
- ✔ Pneumatic rack and pinion actuators are used for valve controls of water pipes.
- ✔ Pneumatic energy quickly responds to starting and stopping signals.
- ✔ The power source does not need to be stored in reserve for operation.

Reference:
https://en.wikipedia.org/wiki/Actuator

- ✔ Pneumatic actuators enable large forces to be produced from relatively small pressure changes (e.g., Pneumatic brakes can are very responsive to small changes in pressure applied by the driver).
- ✔ It is responsible for converting pressure into force.

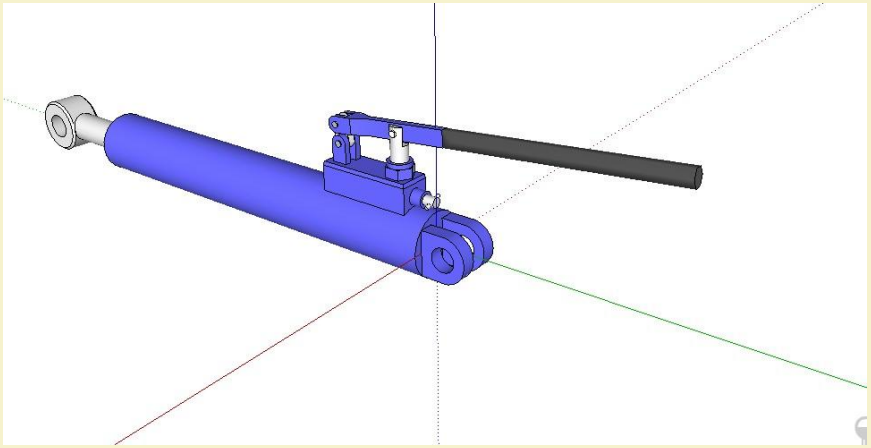


Fig: A manual linear pneumatic actuator

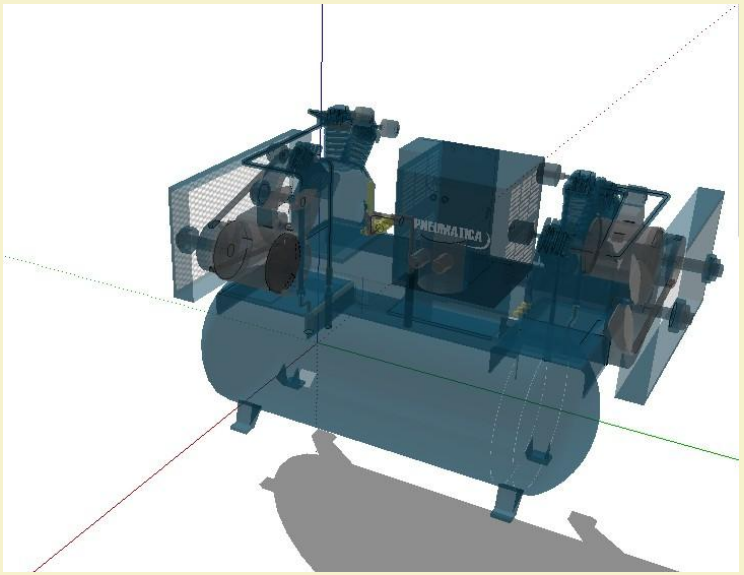


Fig: An air pump acts as a pneumatic actuator

Electric Actuators

- ✔ An electric actuator is generally powered by a motor that converts electrical energy into mechanical torque.
- ✔ The electrical energy is used to actuate equipment such as solenoid valves which control the flow of water in pipes in response to electrical signals.
- ✔ Considered as one of the cheapest, cleanest and speedy actuator types available.

Reference: https://en.wikipedia.org/wiki/Actuator

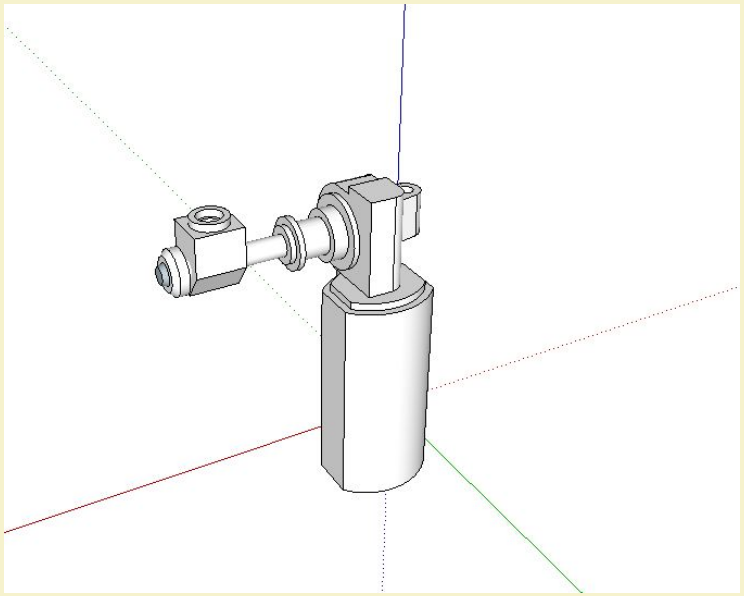


Fig: A motor drive-based rotary actuator

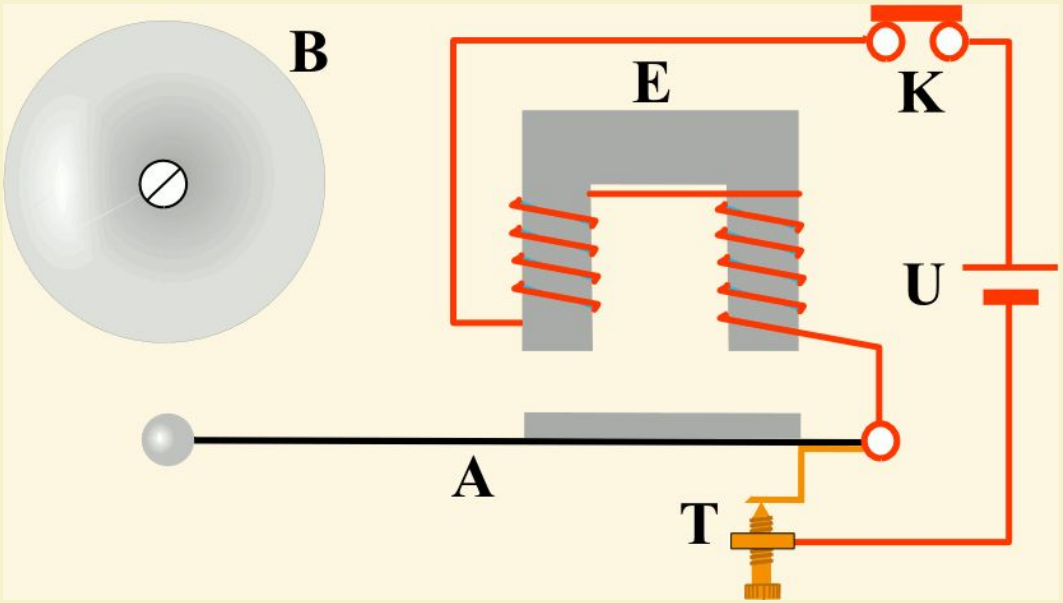


Fig: A solenoid based electric bell ringing mechanism

Source: Wikimedia Commons
File: Electric_Bell_animation.gif

Thermal or Magnetic Actuators

- ✔ These can be actuated by applying thermal or magnetic energy.
- ✔ They tend to be compact, lightweight, economical and with high power density.
- ✔ These actuators use shape memory materials (SMMs), such as shape memory alloys (SMAs) or magnetic shape-memory alloys (MSMAs).
- ✔ Some popular manufacturers of these devices are *Finnish Modti Inc.* and *American Dynalloy*.

Reference: https://en.wikipedia.org/wiki/Actuator

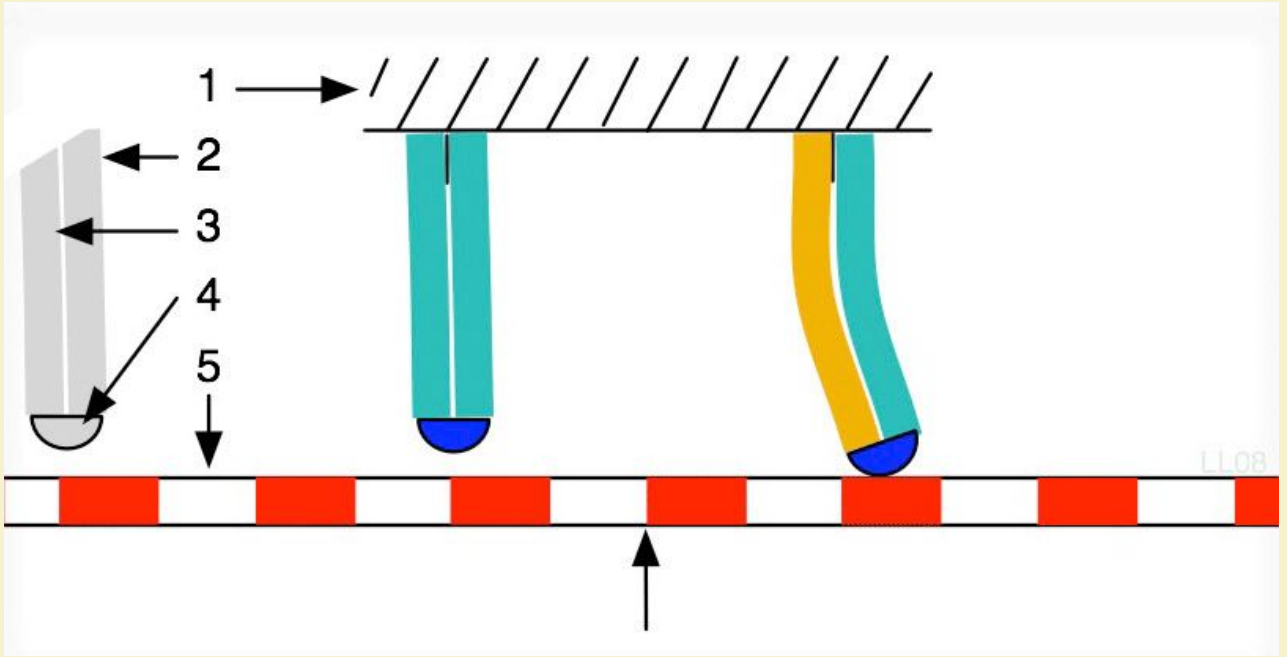


Fig: A piezo motor using SMA

Source: Wikimedia Commons

File: Piezomotor type bimorph.gif

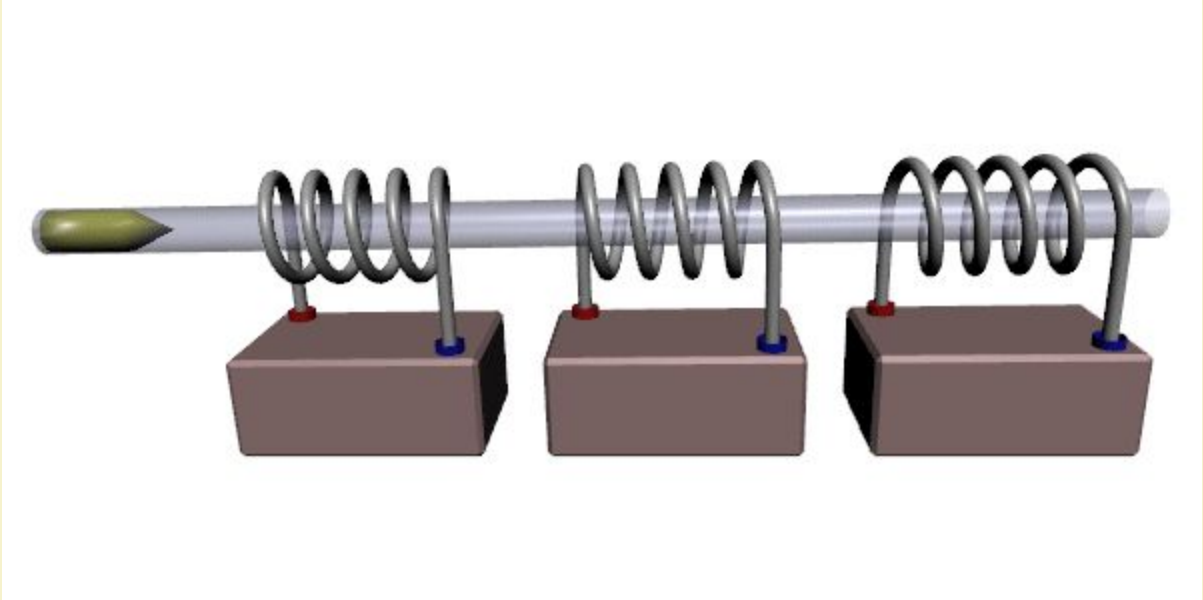


Fig: A coil gun works on the principle of magnetic actuation

Source: Wikimedia Commons
File: Coilgun animation.gif

Mechanic al Actuators

- ✔ A mechanical actuator converts rotary motion into linear motion to execute some movement.
- ✔ It involves gears, rails, pulleys, chains and other devices to operate.
- ✔ Example: rack and pinion.

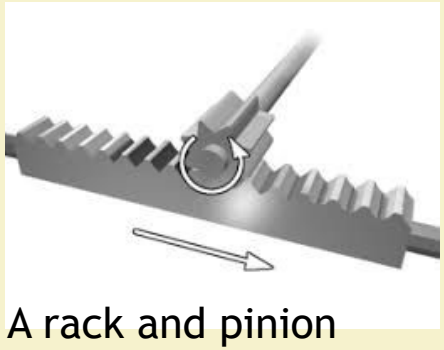


Fig: A rack and pinion mechanism

Source: Wikimedia Commons

File: Rack and pinion.png

Reference:
https://en.wikipedia.org/wiki/Actuator

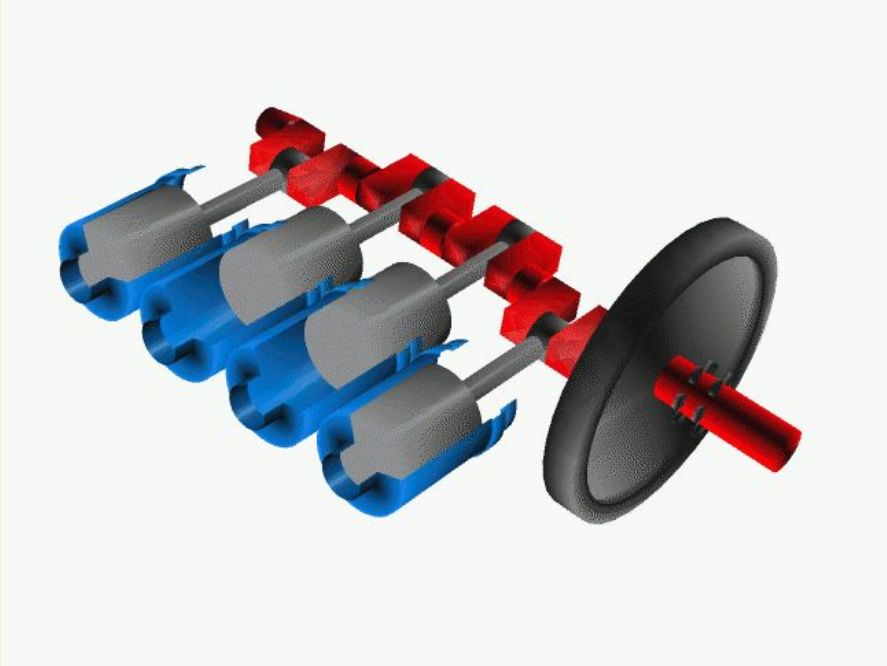


Fig: A crank shaft acting as a mechanical actuator

Source: Wikimedia Commons
File: Cshaft.gif

Soft Actuators

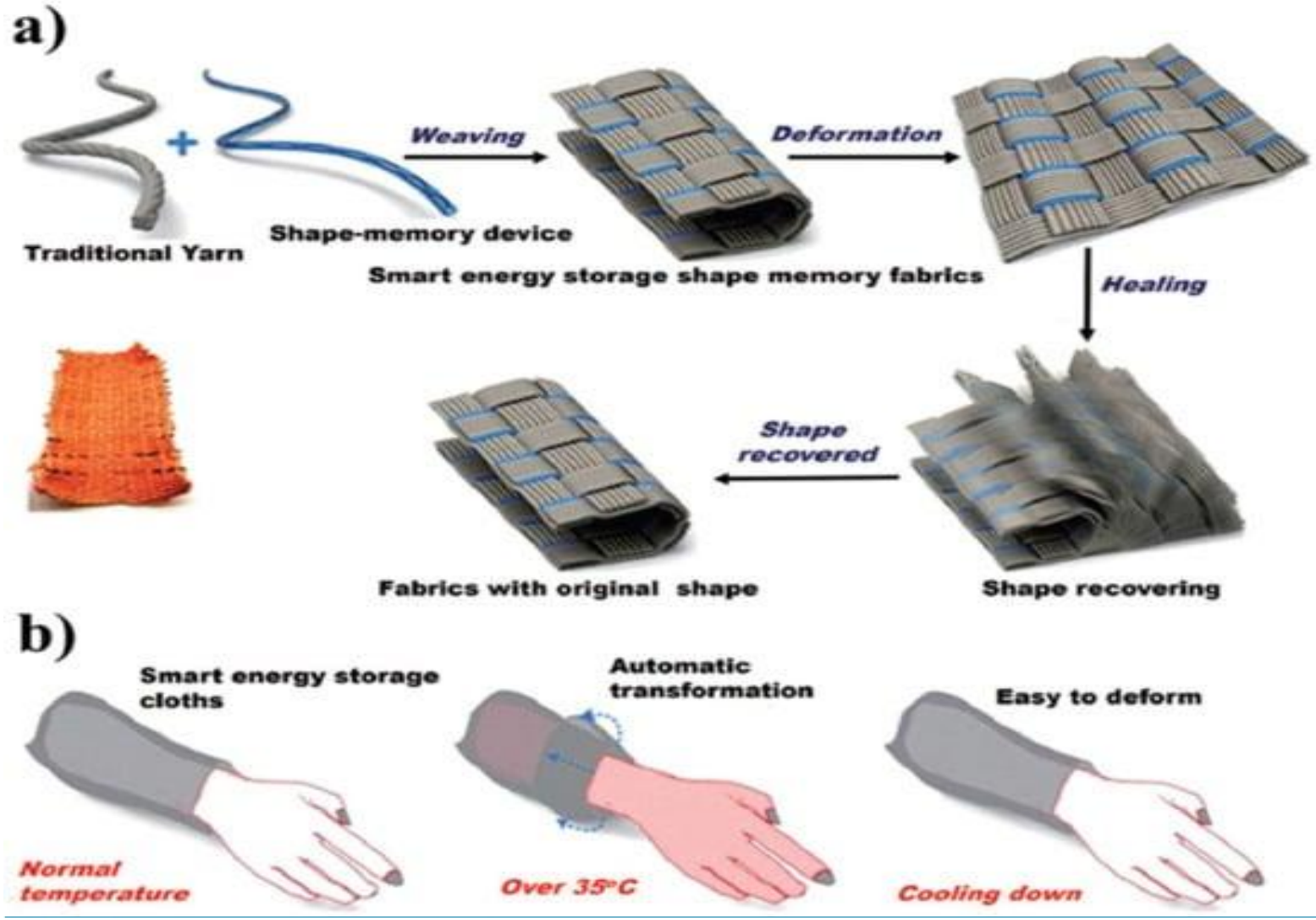
- ✔ Soft actuators (e.g. polymer based) are designed to handle fragile objects like fruit harvesting in agriculture or manipulating the internal organs in biomedicine.
- ✔ They typically address challenging tasks in robotics.
- ✔ Soft actuators produce flexible motion due to the integration of microscopic changes at the molecular level into a macroscopic deformation of the actuator materials.

Reference: https://en.wikipedia.org/wiki/Actuator

Shape Memory Polymers

- ✔ Shape memory polymer (SMP) actuators function similar to our muscles, even providing a response to a range of stimuli such as light, electrical, magnetic, heat, pH, and moisture changes.
- ✔ SMP exhibits surprising features such a low density, high strain recovery, biocompatibility, and biodegradability.

Reference:
https://en.wikipedia.org/wiki/Actuator


a)
Traditional Yarn
Shape-memory device
Weaving
Smart energy storage shape memory fabrics
Deformation
Healing
Shape recovering
Shape recovered
Fabrics with original shape
b)
Smart energy storage cloths
Normal temperature
Automatic transformation
Over 35°C
Easy to deform
Cooling down


Aerospace
Automobile
Smart textiles
SMP
Robotics
Smart tools
Medical devices
(e.g. druy delivery)
Information carriers
(e.g. 2D barcode)
Flexible electronic devices
(e.g. flexible mobile phones)

Light Activated Polymers

- ✔ Photopolymer/light activated polymers (LAP) are a special type of SMP that are activated by light stimuli.
- ✔ The LAP actuators have instant response.
- ✔ They can be controlled remotely without any physical contact, only using the variation of light frequency or intensity.

Reference:
https://en.wikipedia.org/wiki/Actuator

Thank You!!