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Types of IoT Devices

Objectives

- Exploring Different Types of IoT Devices (Sensors, Actuators), its classification
- Outline of Simple sensing operation
- Functional Blocks of Sensor Node
- IoT sensor selection characteristics, and sensing types
- Basics of Sensors signal processing and Sensing considerations
- Hands-on Exercise: Sensor Selection Criteria and Configuration Basics

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Recommended Book

https://www.amazon.in/Internet-Things-Surya-Durbha/dp/0190121092/ref=cm_cr_arp_d_bdcrb_top?ie=UTF8

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Exploring Different Types of IoT Devices

IoT Devices, Sensors, Actuators, and it's classification

IoT Device

IoT device is a piece of equipment with the **mandatory** **capabilities of communication and optional capabilities of sensing, actuation, data capture, data storage and data processing**. The devices collect various kinds of information and provide it to the information and communication networks for further processing.

Some devices also execute operations based on information received from the information and communication networks.

Source: Recommendation ITU-T Y.2060

IoT Devices

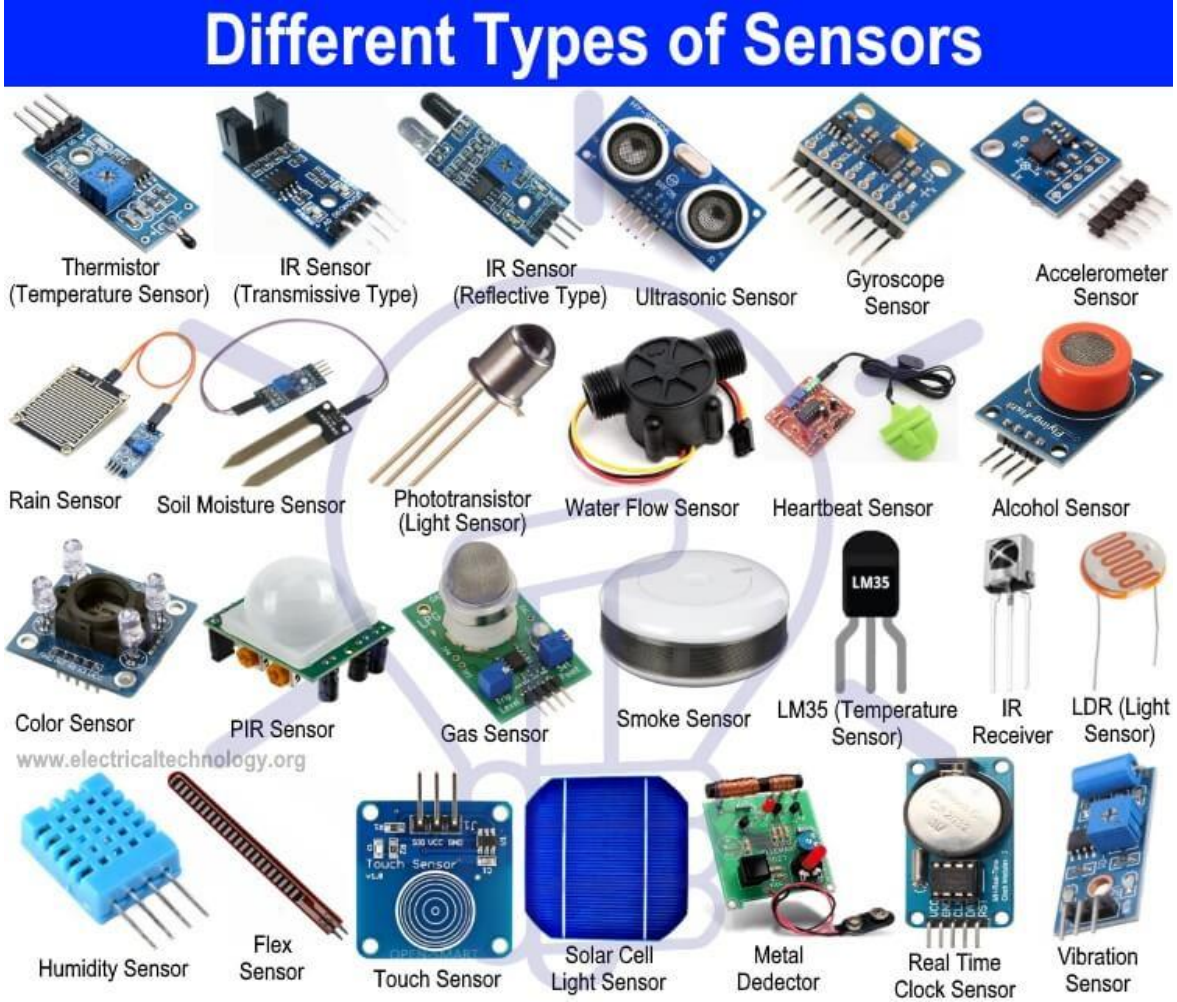
- Sensors - Types and Uses
- Actuators - Types and Uses

Sensors

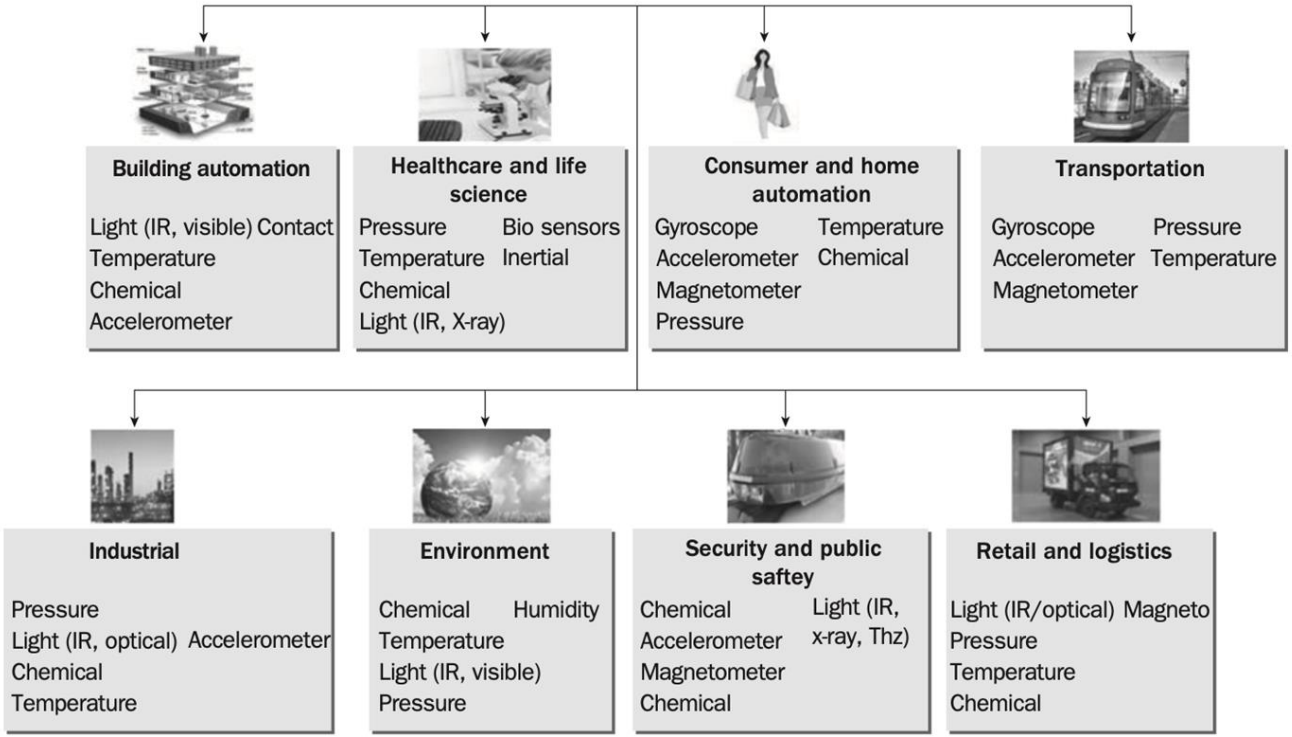
- Sensors a hardware component
- Measure or identify a particular quantity
- Physical objects that interpret environmental changes
- Convert those changes to electric signals
- Convert physical quantities to electrical signals understood by machines

Sensor Classification

- Active or Passive - Power source
- Analog or Digital - Output type



Source: https://www.electricaltechnology.org/wp-content/uploads/2018/11/Types-of-Sensors.jpg



Examples of Sensors

Source: Internet of Things, Durbha et al.

Active Sensor

- Require external sources of energy for its operation
- External energy - electrical, mechanical, other
- Self generating devices
- Example: Strain gauges, pressure sensitive, produce an output voltage in proportion to the amount of force/strain applied to the sensor

Working of Strain Gauge Sensor

https://www.youtube.com/watch?v=Mts5Cr_BNCg

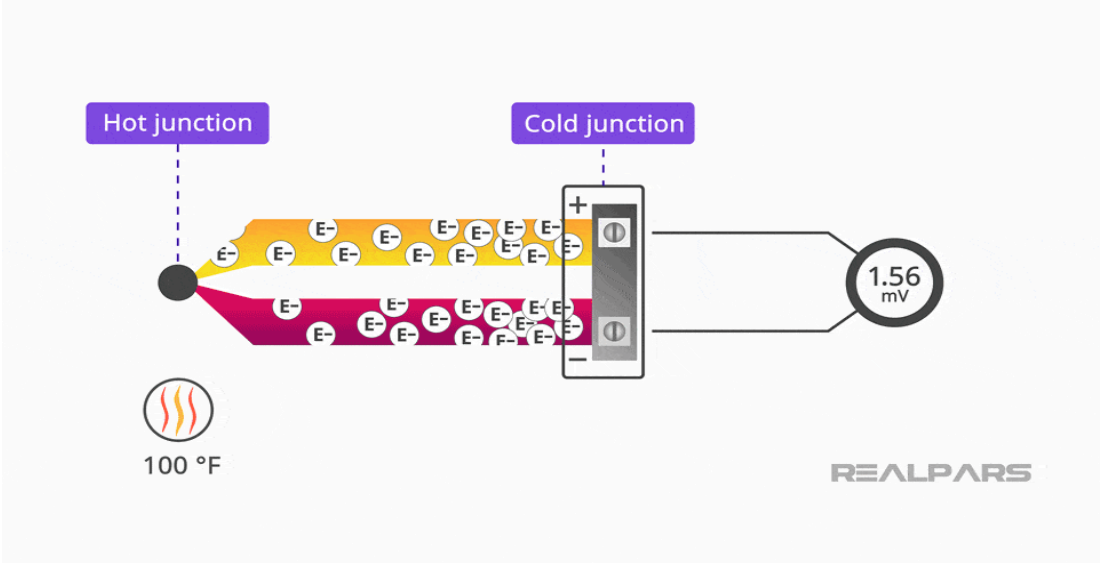
Passive Sensor

- Do not need any external source of energy
- Sensor generates an output signal in response to external stimulus
- Are direct sensors which change their physical properties, such as resistance capacitance or inductance
- Example - Thermocouple, generates own voltage output when exposed to heat

Thermocouple

Source: www.electronicscomp.com

Thermocouple Working



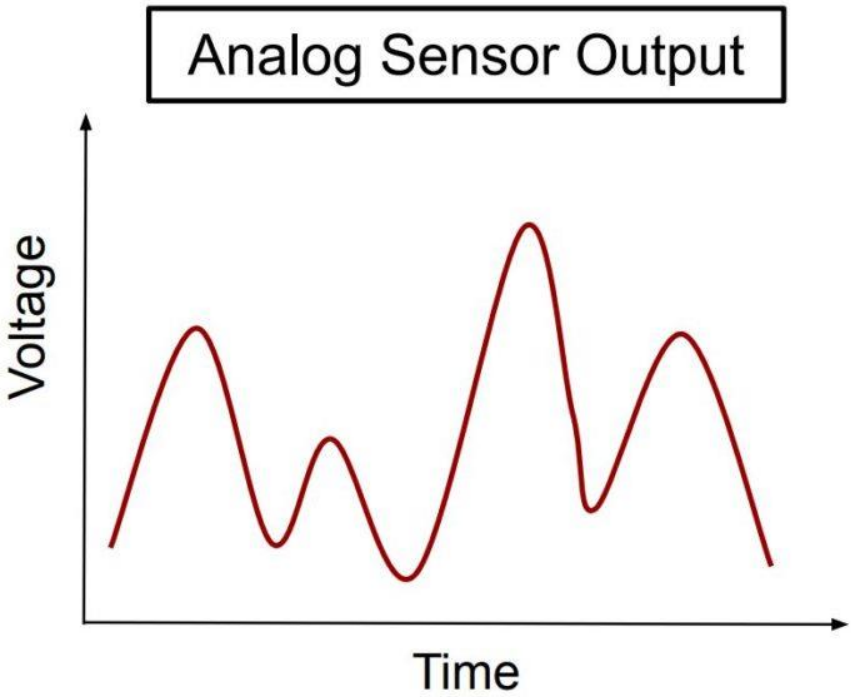
Source: https://www.realpars.com/blog/thermocouple

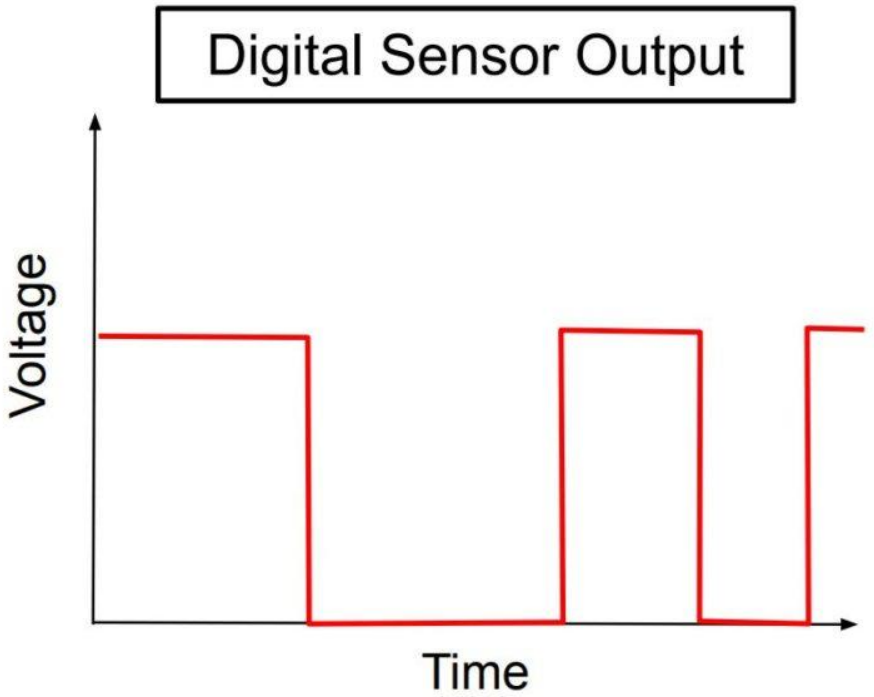
Analog Sensor

- Senors producing an analog output
- continuous signal, fine grained output
- Trades efficiency for more continuous and accurate signal

Digital Sensor

- Sensors producing an digital output
- Discrete signal
- Free from issues of analog sensor





Source: https://www.smlease.com/entries/automation/what-are-different-types-of-sensors-and-their-applications/

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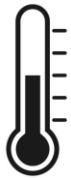
Outline of Simple Sensing Operation

Overview of sensing operation

Outline of Sensing Operation

Environment

Sensing



Processing

Monitoring

Source: different sources

Commonly Used Sensors

- Light Sensors
- Accelerometers
- Gyroscopes
- Magnetometer
- GPS
- Proximity Sensor
- RFID

Sensors in Mobile Phone

Source:https://www.researchgate.net/figure/Built-in-sensors-in-a-typical-present-day-smartphone_fig2_332973899

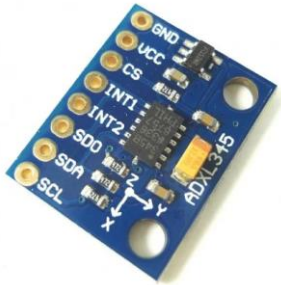
Light Sensor

- Converts light energy into electrical signals
- Also known as photoelectric device or photo sensors
- Passive device
- Change in light intensity interpreted as change in voltage

Image Source:
https://www.engineersgarage.com/light-sensors-ldr-photodiode-phototransistor-solar-cell/

Accelerometers

- Electromechanical device
- Measures vibration, or acceleration of motion, of a structure
- Force caused by vibration or acceleration causes mass to squeeze
- Produces electrical change proportional to force exerted



Source: https://robu.in/

Actuators

A device which takes action as per the input command, pulse, state

Converts one form of energy into some other form of energy

Motor, speaker, LED or an output device converts the electrical signal into physical action

Piezoelectric vibrator : Piezoelectric crystals when applied varying electric voltages at input generates vibrations

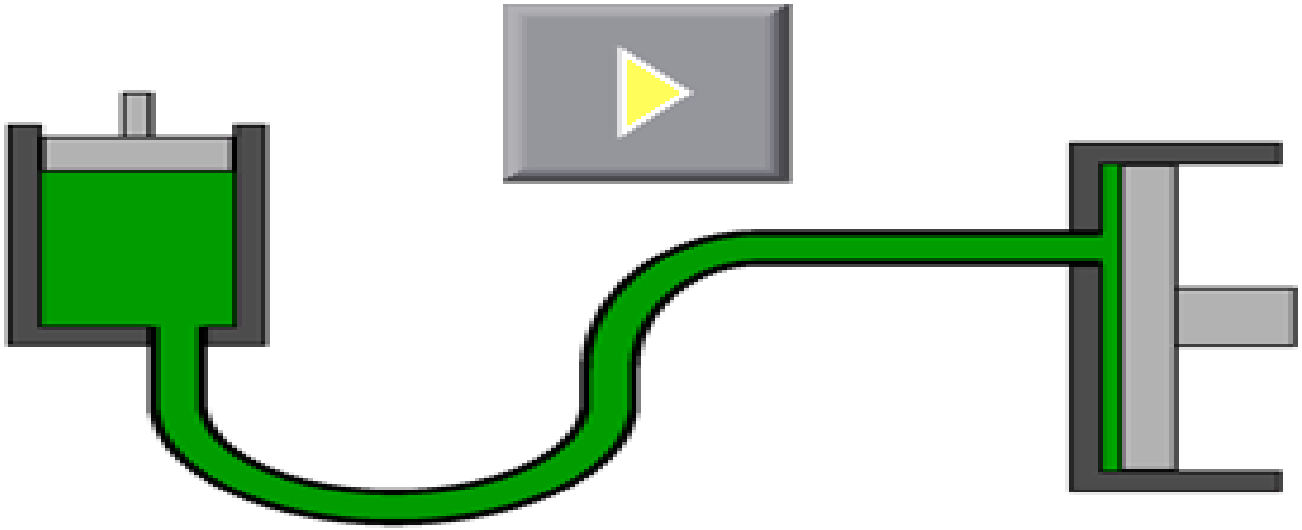
Types of Actuators

- Hydraulic
- Pneumatic
- Electrical
- Thermal

- Mechanical
- Soft
- Shape Memory Polymers

Source: Images from different source

Hydraulic Actuators



Source: wiki

Hydraulic Actuators Contd..

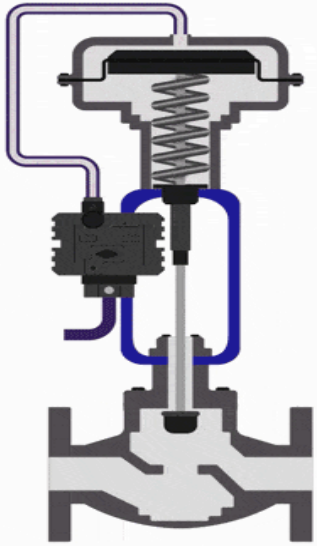
Advantages

They have high speed and can produce a large magnitude of force.

Disadvantages

Fluid leakage can cause various maintenance issues. It is expensive and requires additional equipment such as heat exchangers and noise controllers.

Pneumatic Actuators



Pneumatic actuator

REALPARS

Pneumatic Actuators Contd..

Advantages

They are durable, have a long operational life and require low maintenance. Air is a safer component to use and can work with very high temperatures.

Disadvantages

To reduce loss of pressure the air compressor must run continuously. Polluted air may require extra maintenance.

Electrical Actuators

Electric actuators are electro-mechanical devices capable of creating an action that requires a force like clamping by using an electric motor. The electric motor converts electrical energy into mechanical torque. They produce simple, safe and clean movements with accurate and smooth motion control. Electric actuators have a long life with a very low total operating cost.

Electrical Actuators Contd..

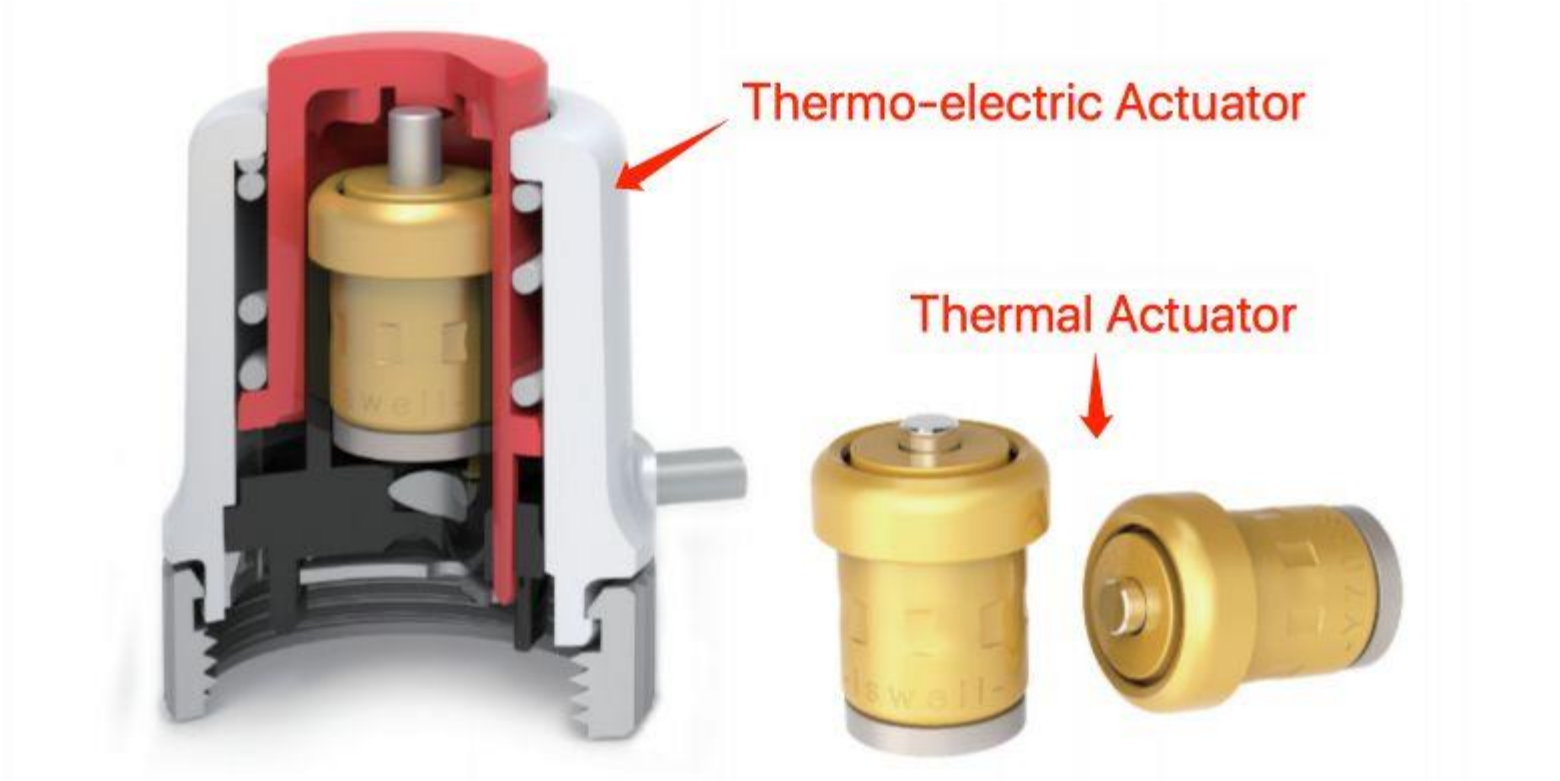
Advantages

Produces less noise and is easy to use. They can be used to achieve high precision.

Disadvantages

It can only be used in places that satisfy certain environmental conditions. It is also expensive.

Thermal Actuators



source:https://waxmotor.com/blogs/introduction-to-thermal-actuator

Magnetic Actuators

Magnetic actuators use magnetic forces to produce motion. Most magnetic actuators work based on the Lorentz Force equation. Based on the components used to produce magnetic and repulsive forces, Magnetic actuators are of 3 types:

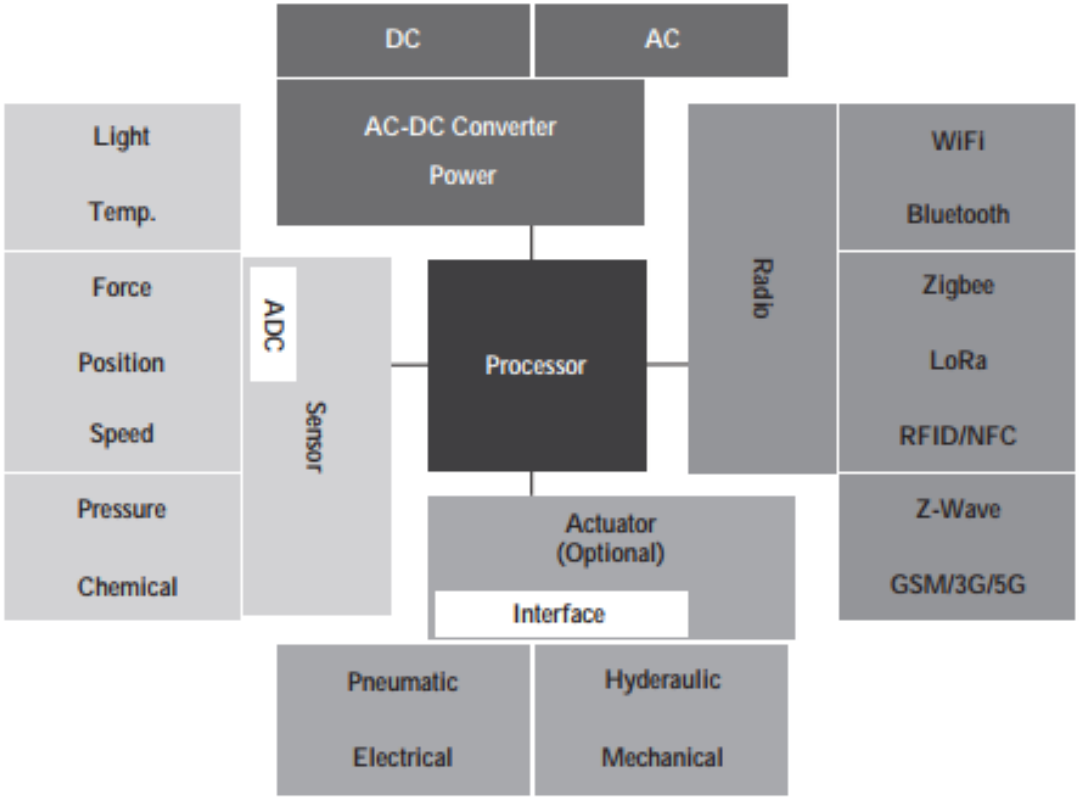
Moving Magnet Actuators, Moving Coil Actuators and Moving Iron Actuators.

Functional Blocks of Sensor Node

Sensor Node components

Sensor Node

- Combination of sensor/sensors, processor unit, radio unit and power unit
- Sense the environment and communicate the information to gateways



Sensor Node

Source: Introduction to IoT Misra et al.

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IoT sensor characteristics and selection factors

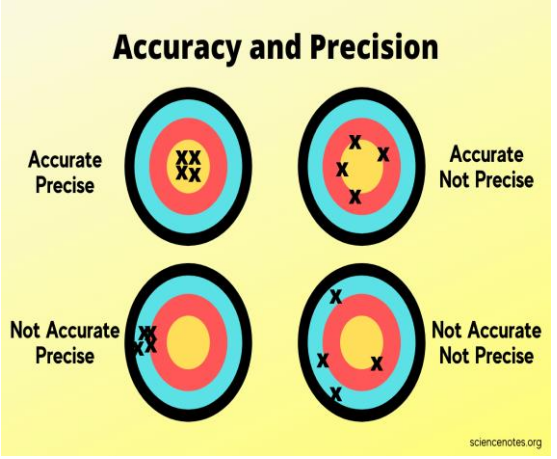
Sensor selection and characteristics

Sensor Characteristics

Sensor Resolution: Smallest change in the measurable quantity the sensor can detect is called as the sensor resolution. More the resolution, the more accurate is the precision.

Sensor Accuracy: Measuring the quantity as close to its true measurement as possible.

Sensor Precision: If on multiple measurements of the same quantity we get the same values, we can say it is high precision sensor.



Selection Criteria

It depends of factors such as:

- Usability
- Design
- Affordability

Important Considerations

Size : crucial form factor, increased power consumption, not suitable for bulk applications (wearables)

Energy: Higher energy requirement, battery replacement needed, lowers long term sustainability

Cost: Important parameter for consideration , cheaper -> more deployment

Memory: decide capabilities of device, data storage, processing, formatting rely on memory (cost)

Important Considerations Contd..

Processing power: type of application, critical factor, interconnection of other sensors

I/O rating: processor in most cases is the deciding factor

Add Ons: additional peripherals, use case, connections etc

Purpose and Use Case

Understanding the device's purpose involves clearly defining the problem the device aims to solve or the service it intends to provide. It includes identifying the target users, environment, and the specific tasks or functions the device will perform within its intended application

Use cases examples - Landslides detection , Agriculture, Hydrology, Home monitoring

Sensors and Data Collection

Sensor selection involves choosing sensors that accurately capture relevant data for the application. Factors include accuracy, precision, range, sampling rate, and compatibility with the environment in which the device will operate

Power Management

Efficient power management is crucial for IoT devices, especially those operating remotely or on battery power. Techniques like sleep modes, low-power components, and energy harvesting methods (solar, kinetic, etc.) help extend battery life or enable continuous operation

Sensing Types

Sensing Types

Sensing Types

Divided into 4 categories:

- **Scalar sensing**
- **Multimedia sensing**
- **Hybrid Sensing**
- **Virtual Sensing**

Scalar Sensing

- Changes can be quantified by measuring changes in amplitude of the measured values with respect to time
- Quantities such as ambient temperature, current, atmospheric pressure, rainfall scalar values
- No directional or spatial property
- Sensors for such scalar sensors

Multimedia Sensing

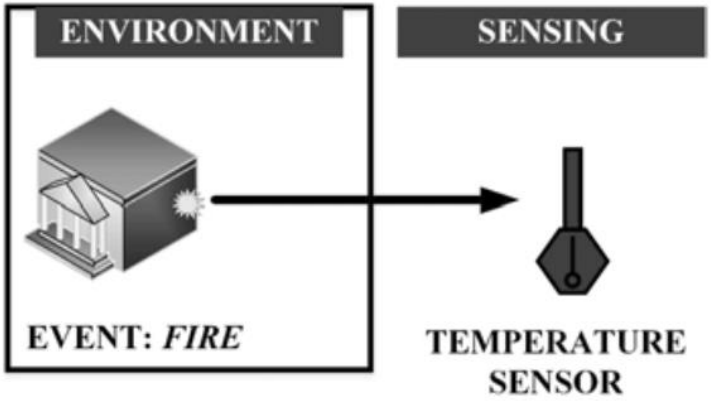
- Sensing of features that have a spatial variance property associated with property of temporal variance
- Used for capturing the changes in amplitude of quantifiable property concerning space (spatial) as well as time (temporal)
- Images, direction, flow, speed, acceleration, sound, force, mass etc have direction and magnitude
- Sensor measuring these quantities called vector sensors

Hybrid Sensing

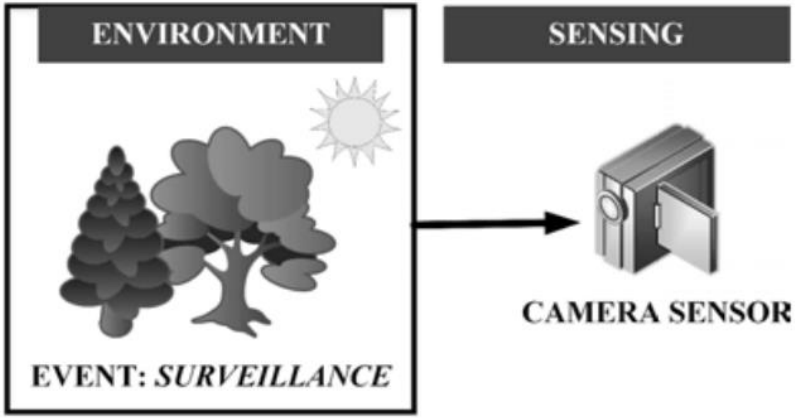
- Using scalar as well as multimedia sensing at the same time
- Need to measure certain vector as well as scalar properties at the same time
- Range of sensors are employed
- Example- Soil moisture sensor with imaging sensor

Virtual Sensing

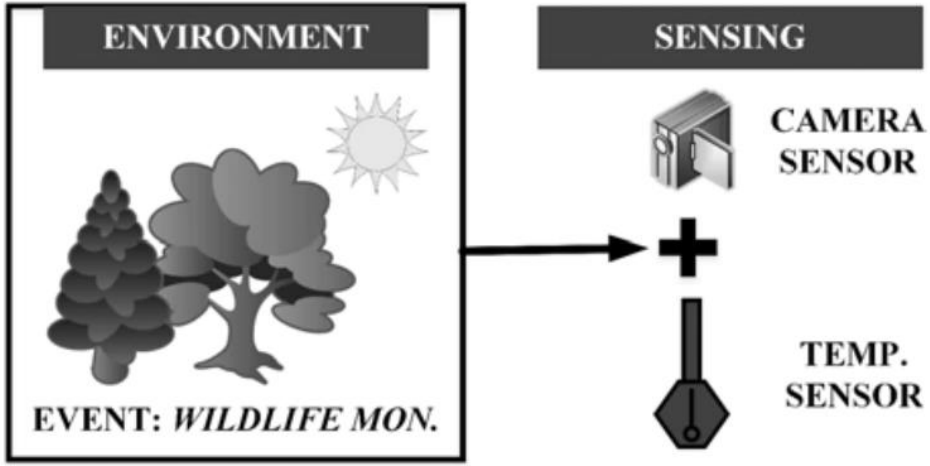
- Creating or estimating sensor data that may not be directly measured
- Based on extending values from dense network of sensor or models
- Used in agriculture large areas as some properties don’t vary spatially much



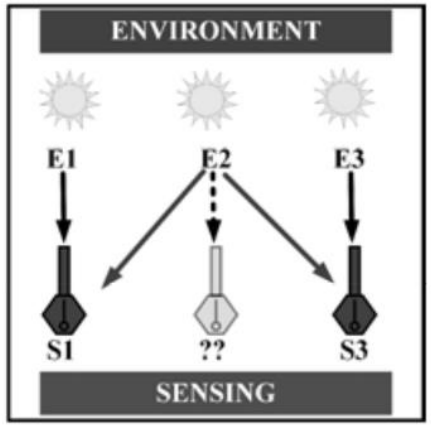
(a) Scalar sensing



(b) Multimedia sensing



(c) Hybrid sensing



(d) Virtual sensing

Source: Misra et. al

Sensing Considerations

Sensing Considerations

Factors affecting selection of sensors:

- Sensing Range
- Accuracy & Precision
- Energy
- Device Size

Sensing Considerations Contd..

Sensing Range: Area covered by the sensor to monitor changes, the number of sensors needed to measure over a certain area.

Accuracy & Precision: Depending on the use case, for industrial applications we will require sensor of higher accuracy and precision. For hobby projects we may not need high precision and accuracy.

Sensing Considerations Contd..

Energy: Energy consumption is a critical for lifetime of device and cost of deployment. Energy replenishment of sensor will also decide the maintenance and feasibility.

Device Size: IoT devices are involved in all domains of life. Smaller size devices are easier to install and not hinder other uses. Larger devices cause obstruction and generally have higher cost and energy consumption.

Introduction to Python Contd..

Simple Operations using Colab

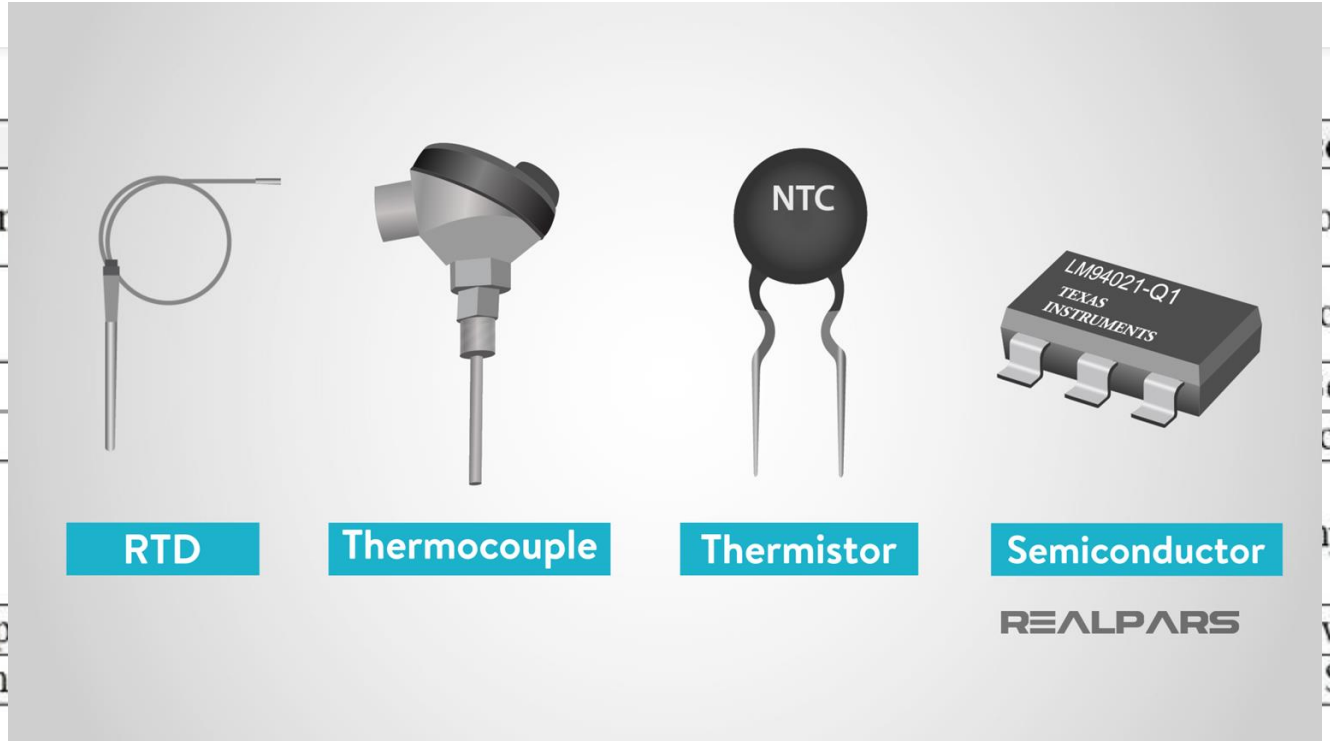
Link for Colab Notebook

Homework

- What are the capabilities an IoT device should have?
- Give an example of active and passive sensor and describe their working?
- What are the important factors for sensor selection?
- What are various sensing types?
- Explain the different types of processing technologies and when which is utilised ?

Hands on Exercise

Criteria				ensor
Temperature ran				o +200°C
Accuracy				ood
Linearity				est
Sensitivity				ood
Circuitry				mplest
Power consump				west
Relative system				$



Source:https://www.mouser.com/blog/what-are-you-sensing-pros-and-cons-of-four-temperature-sensor-types

Summary

- We learned about IoT devices, sensors, actuators, different types of of sensors and actuators.
- Overview of sensing operation
- Sensor selection characteristics, and sensing types
- Sensor signal processing and sensing considerations

Thank you!