Chapter: 5 Sensors and Actuators in IoT

Introduction:

* The end device of any IoT system is either a sensing device on one end or an actuator on other end that triggers action as an output. Hence it is also known as "Edge Device".
* The edge device/node is connected to network by wireless/wired network.
* Data integrity is major issue as data is collected from signals from many sensors for intelligent decision making.
* The device at edge is capable of sensing, pre-processing, measuring, interpreting and connecting to the cloud through gateway for providing intelligence.
* Edge nodes with a processing unit are larger in size, compared to end nodes.

Ex. of edge nodes:

Sensors: light, sound, pressure, temperature, humidity, vibrations, motion, accelerometer, gyroscope, GPS, proximity, magneto, gas, RFID, NFC, flow meters, ultrasonics, camera, etc.

Actuators: switch, relays, PLCs, motors, light, sound, etc. LED, OLED, Buzzer

* Sensors must be identified by IP addresses.
* Smart Sensor - Interfacing sensor with microcontroller.

Sensors for Different IoT Applications:-

Healthcare: Light sensors, biosensors, motion & acoustic sensors.

Building automation: ultrasonic sensor for smart parking; PIR sensor for smart waste management & temperature sensor for room temperature monitoring.

Agriculture: soil moisture, pH sensors, solar radiation, soil nutrients. Light - HCSR501, Distance - HCSR04.

weather sensors - temperature, relative humidity, wind speed/direction, barometric pressure.

Perception Layer of IoT:

* IoT architecture - perception, network, application layers.
* Physical layer also known as perception layer which consists of sensor devices for sensing & collecting information from environment. Task is to identify other smart objects in environment.

Active sensors:

* Sensors which require external source of energy for its operation.
* The external energy can be mechanical, electrical, etc.
* widely used in networking & manufacturing applications.
* It is a device with a transmitter, which sends a signal that bounces back from target, reflected data is gathered by sensor.

Passive Sensors:

* Does not require any external energy source for its operation.
* Sensors such as accelerometers, magnetometers, barometer, are able to extract a measurement without interacting with surrounding environment by sending some form of signal.

⇒ Remote sensing technology used in both active & passive.

⇒ Seismic & Infrared light sensors ~~used in both~~ are both active & passive

Understanding Some commonly used Sensors:

(1) Light sensors:

* Convert light energy (photons) - electronic signals-known as photoelectric devices (or) photo sensors.
* The light sensor is passive
* A beam of light is used to detect presence, emitted from light-emitting element.
* For detecting the light beam, a reflective-type photoelectric sensor is used.
* Light intensity sensors are: photoresistors, phototransistors, photodiodes.

(2) Accelerometers:

* Electromechanical device, forces are measured.
* Both static [force of gravity] & dynamic force [by vibrating accelerometer]
* Produces analog (or) digital outputs.
* Analog's accelerometer output is continuous voltage of acceleration
* Digital's accelerometer use PWM for output.
* Piezoelectric effect & change in capacitance is sensed - other ways accelerometers use.
* Piezoelectric accelerometer - for high frequency applications, due to its compact size.
* Seismic mass accelerometer - Based on relative motion b/w a mass and supporting, for low-to-medium frequency applications.

(3) Gyroscopes

* Consists of rotor mounted at centre of a larger spinning axis.
* Angular velocity is sensed by gyrosensors
* Uses Earth's gravity to determine orientation based on principles of angular momentum
* 3 types - rotary, vibrating structure & optical.

(4) Magnetometer

* measures strength, direction or relative change of magnetic field.
* Applications - compass, detecting metal objects under water, various surveys for minerals & oil exploration.

(5) Global Positioning System

* GPS use satellites & ground stations to decide & compute a position on earth.
* GPS receivers collects data from atleast 4 satellites for accurate GPS computation.
* GPS receivers used in applications such as - smartphones, military applications, fleet management system etc.

Working principle of GPS:

- GPS on satellites → Information signal (radio frequency range 1.1 - 1.5 GHz) → Receiver using constellation of satellites & ground stations
- GPS module, with this received information, can compute its own position & time.

GPS Distance Calculation

* Calculates using the time required for signal to reach to receiver.
* Synchronized pseudocode signal — by both satellite & GPS receiver.
* These signals are compared & difference between signals is computed.
* Receiver computes the distance from information signals received from three/more satellites & then it can calculate its location by using Trilateration method.

(6) Proximity Sensors:-

* Emit a beam of electromagnetic radiation & any change in field results in a return signal.
* Have capability to detect presence of objects in their vicinity without any physical contact
* Four types: capacitive proximity sensor, inductive proximity sensor, photoelectric/optoelectronic sensor, ultrasonic proximity sensor
* Application areas – detection, position, inception, manufacturing systems
* Capacitive sensors – any change in dielectric medium surrounding the active face, also sense any object beyond a layer of thin carton, glass/plastic
* Inductive proximity sensors –
  - can sense & respond to ferrous & non-ferrous metal objects.
  - when a ferrous object is nearby, change in inductance of sensor takes place, that converted to voltage to operate a switch.

(7) Radio Frequency Identification (RFID):-

* Uses RFID tag (chip with antenna) to embed data in it with an RFID reader.
* Unlike bar code, line of sight communication is not required b/w tag & reader.
* Radio waves are used to transmit data stored in tag. Upto 100s of meters

Near RFID:-

- In reader, a coil through which AC is passed & magnetic field is generated. change in magnetic field is registerd by tag, generates a potential difference. Voltage is coupled with capicator that powers up tag chip.

Far RFID:-

- A dipole antenna is present in reader, used for propagating EM waves & for sensing the alternating potential difference.

* The object to be tracked is attached with RFID tag & reader detects its presence when the object passes across it
* RFID tags:
  - active – external power/energy source is associated.
  - passive – do not need any external source, cheaper option for long ~~time~~ lifetime.
* Authorized object with RFID tag is useful for access control
* Applications – Object tracking, supply chain management, identity authentication, access control

Environmental Sensors:

(1) Temperature Sensors:

* amount of heat or coldness that is generated by an object is measured by temperature sensor.
* either by analog or digital output.
* 2 basic physical types - contact & non-contact temperature sensor
* Contact: require physical contact with objects to be sensed & use conduction principle of heat to monitor changes in temp.
* Non-contact: Use convection & radiation heat principles to monitor changes in temperature.
* Common devices are thermistors, RTDs, Infrared & thermocouples.
* Thermistors - semiconductor devices that change the resistance with temperature change. 100°C range, high sensitivity
* RTDs - principle that resistance of metal changes with temperature.
* Infrared - use radiation head.

(2) Pressure Sensors:

* used for control & monitoring. Also measures water level, fluid/gas flow, altitude & speed.
* work as pressure sensors to turn on/off a particular pressure value [water pump controlled by pressure switch]
* very high pressure changes occuring in dynamic mode are captured by some specially designed pressure sensors. [measuring combustion pressure in gas turbine].

(3) Humidity Sensors:

* 3 types - thermal, capacitive and resistive.
* Based on humidity of surrounding air, two thermal sensors conduct electricity. One is encased in dry nitrogen, while the other is open in ambient air.
* Relative humidity is measured by placing a thin strip of metal oxide between two electrodes. Electrical capacity of metal oxide changes with the relative humidity of atmosphere.
* Application areas are: sensing, building & construction, health monitoring & medical applications, fuels, aerospace, indoor, etc.

Relative humidity Sensor:
- RHS is used for monitoring Agriculture, weather studies, discharges, etc. encased with integrated circuit. [0-95%]

Wind speed and Wind direction Sensors:
* Wind vanes measures wind direction, wind speed by anemometers.

(5) Soil moisture Sensors:
* not only soil moisture, also can measure water potential. Such sensors include tensiometers & gypsum blocks, property called as soil water potential.
* soil moisture affects reflected microwave radiation.
* This measure is useful for drawing inferences in remote sensing hydrology & agricultural applications.

(6) Leaf sensors: (phytometric devices)
* Are mounted on randomly selected leaves on plant.
* measurements at 5-min intervals throughout day & determine whether the plant is with enough water content / water stressed.
* avoid over-watering / under-watering a crop.

(7) Lysimeter:
* A device which measures the amount of actual evapotranspiration which is released by plants.
* Amount of precipitation, amount of water lost through soil & through evapotranspiration.
* 2 types: weighing & non-weighing

(8) Rain Guage:
* measures the amount of rainfall of any area in a given time period.
* Rainfall is measured in inches / millimeters. Based on collected data, intelligent decision making is possible about land & crops.

(9) Chemical Sensors:
* Detects chemical & biochemical substances.
* made of transducer & recognition element.
* e-Tongue & e-nose are being developed to sense taste & odour
* Applications are - monitoring pollution level in smart cities, testing food, agricultural products & checking food quality in smart kitchens, medical, automotive, detection of harmful gases indoor such as CO.

Medical Sensors

① HeartBeat Sensor:
Heartrate varies heartbeat varies
→ Manual way: measured by checking pulse in wrist (radial pulse) and neck (carotid pulse)
→ sensors use: measured using optical power variation as light is scattered during its path through blood

② Pulse Sensor: captures heartbeat / heartrate of a person
appln: health bands, advanced gang consider, sleep tracking

③ Blood Glucose Level Sensor:
- by continuously monitoring the condition of blood glucose by placing a transmitter implanted in body

④ Blood Pressure Sensor:
- is a non-invasive sensor.
- systolic, diastolic, and mean arterial pressure are measured by oscillator technique

⑤ Body Temperature Sensor,

Flow & fluid measuring Sensors:-

① Level sensors: detects level of liquid (or) semi-solid material in an closed space (or) free-flowing
→ point measurements (or) continuous

② Stream Guage:
→ Terrestrial bodies of water are tested & monitored by stream guaging station
→ Data from these network of station's are made accessible.

③ Tide Guage: (Mareograph)
→ measure change in sea level relative to vertical datum.
→ mean sea level is used as vertical datum.

Range & Motion Capture Sensors:

detects movement of objects.

measure distance of an object

PIR sensors: 12 meters, motion detection of humans, vehicle movement detection, animal movements.

① Ultrasonic Distance sensor: 21 m, 2cm - 400cm, 1s,
appl: liquid level measurements, trash cans, people detection, industrial production lines

② Laser Distance sensors: works well under varying light conditions
appln: building, construction, oil & gas mining, electronics, etc.

Touch sensors:
displays of smartphone, tablets.
capacitive; Capacitive coupling to sense a thing whose dielectric diff.
Resistive; glass / polycarbonate } support material & film are coated with ITO - Indium Tin Oxide
↓
has high electrical conductivity.

Actuators:
* is a device that converts the effective change in the env. sensed in the form of electrical energy into other form of energy.
* based on operation - electrical, hydraulic (hydraulic power), pneumatic (pressure), actuator.

① Servo motors:
- To push or rotate an object.
- DC & AC; small & light weight package with high torque.
appln: robotics, RC helicopters, machine toy cars etc.

② Stepper motors:
→ is an electromechanical device, it converts electrical power into mechanical power.
→ Brushless, synchronous electric motor, full rotation is divided into expensive no. of steps
types - permanent magnet stepper.
- hybrid synchronous stepper
- Variable reluctance stepper.
→ Appln: • actuators in fluid pumps, medical scanners, blood analysis machines, respirators.
• in digital cameras for focus & zoom.
• machine tooling equipment, automotive gauges, surveillance systems

③ DC motors: electrical energy converted by motor to produce mechanical energy.
DC motor: fixed windings provide mg. flux & armature of motor acts as conductor.
* Principle → current carrying conductor placed in a magnetic field will experience force that causes rotation wrt the original position.
- rotor, stator.

④ Linear Actuators:
* used when motion in a straight line b/w two points is required.
* mechanical (or) electromechanical devices.
* rotation of electric motor is converted to linear motion by using gears & lead screw.
appln: valves, automatic windows/doors, robotics, machine design, industrial equipment etc.

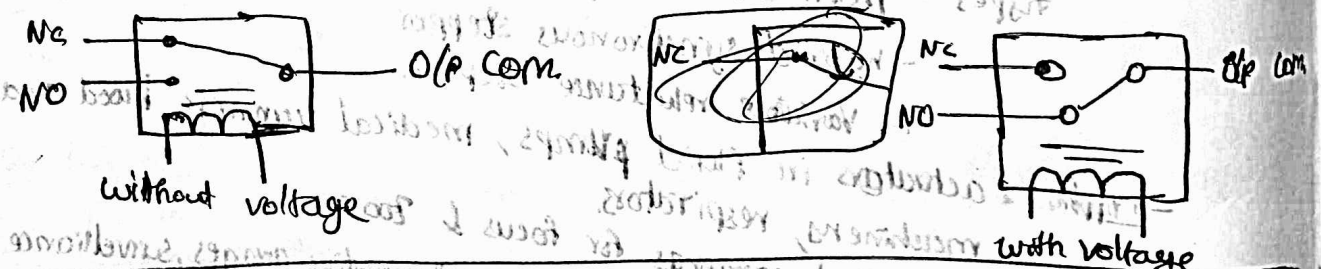
⑤ Solenoid: (a coiled wire around a cylinder)
→ when current runs through solenoid, strong magnet is generated,
electromagnet can be on/off, ↑ strength by ↑ current flow,
applns: valves, pistons, home automation (doorbells, autolocks, AC), sprinkler systems, automobiles (engine starters), etc

⑥ Relays: → receives I/P signal from one side & controls switching operation on the other side.
↳ like a switch that controls the circuit electromechanically,
Parts of relays: • electromagnet, movable armature, contacts, spring, yoke

Relay types:
Based on operation principle → solid state relay
→ hybrid "
→ electrothermal "
→ electromechanical "

Based on polarity → Polarized relay
→ non polarized relay

applns: home appliances, home/office automation (heating, cooling, lighting), precision agriculture, automative appln, industrial appln.



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Part-B