CSC 4255 –
IoT System Design and Implementation

IoT devices & IoT communication protocols

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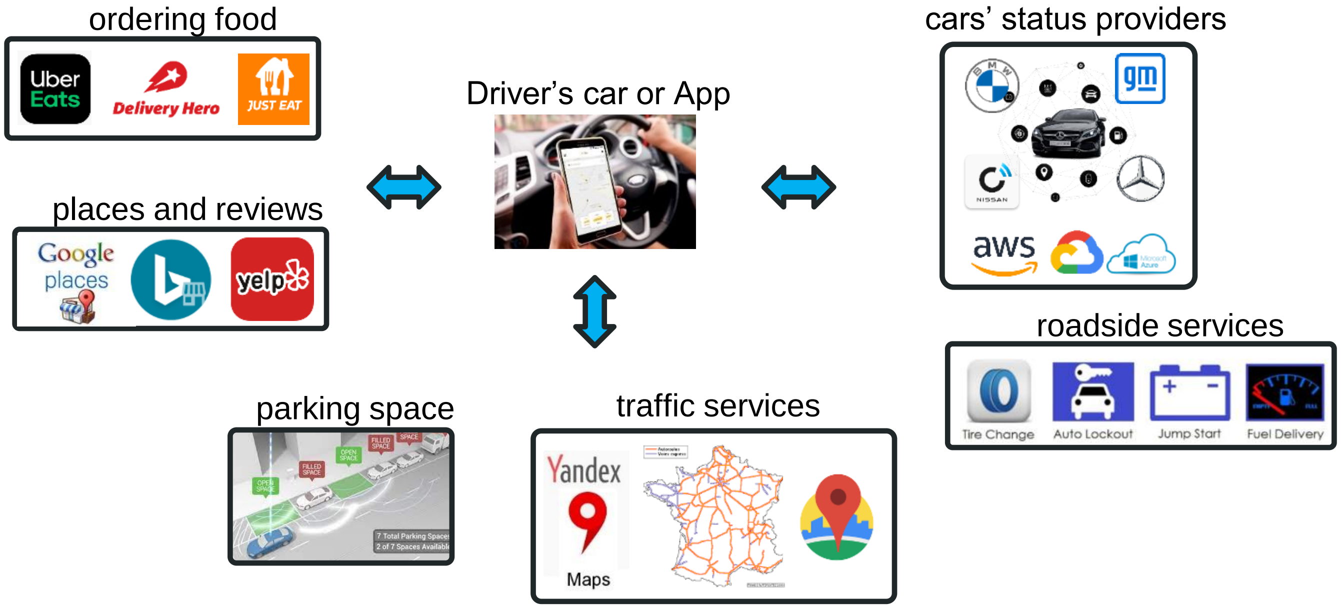
Outline

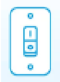
- The “Things” in the IoT
- Sensors & Actuators
- Smart Objects
- Conclusion

Connected Roadways thanks to the IoT

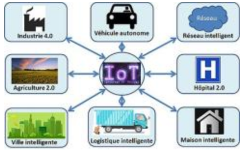
- IoT allows self-driving vehicles to “better” interact with the transportation system
- Also called IoV (Internet of Vehicles)



The “Things” in connected roadways

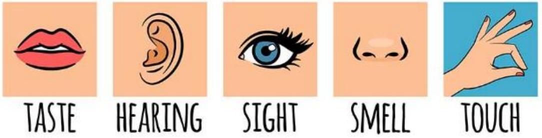
- **Sensors** of all types: temperature, location [GPS], pressure, velocity 
- Embedded technology to ***sense*** and/or interact with their environment 
- **Actuators** to control cars and improve safety 
- **Smart objects** process “raw data” for meaningful and relevant data 

- **Applications** to improve driver experience and simplify vehicle maintenance
- **Communication nodes** for the above to interact with each other



Sensors (1)

- A sensor “It senses”:
  - It measures some physical quantity and converts that measurement reading into a digital representation
- Digital representation → transformation into meaningful data
- Human senses:
  - Five senses to learn about their surroundings (not operating in silos)



  - Brain: ultimate decision maker
- Sensors: superhuman sensor capabilities
  - extremely wide spectrum of rich and diverse measurement data

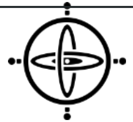
Sensors (2)

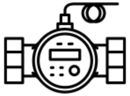
- Categories of sensors:
    - *Active* emit energy for measuring; *Passive* detect emissions
    - *Invasive* part of the environment they are measuring; *Non-invasive* external to the environment
    - *Contact* if require physical contact; or *No-contact*
    - *Absolute* if they measure on an absolute scale; *Relative* if based on variable reference value
    - *Area of application*
    - *How sensors measure*, e.g., thermoelectric, electrochemical, piezoresistive, optic, electric, fluid mechanic, photoelastic
    - *What sensors measure:* apps or physical variables they measure

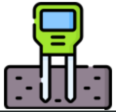
Sensors (3)

- Classify based on what physical phenomenon a sensor is measuring
    - *Position* (Potentiometer, inclinometer, **proximity sensor**)
    - *Occupancy and motion* (Electric eye, **radar**)
    - *Velocity and acceleration* (**Accelerometer**, gyroscope)
    - *Force* (Force gauge, viscometer, **tactile (touch) sensor**)
    - *Pressure* (Barometer, Bourdon gauge, piezometer)
    - *Flow* (Anemometer, **mass flow sensor**, water meter)
    - *Acoustic* (Microphone, geophone, **hydrophone**)
    - *Humidity* (Hygrometer, humistor, **soil moisture sensor**)
    - *Light* (**Infrared sensor**, photodetector, flame detector)
    - *Radiation* (Geiger-Müller counter, scintillator, **neutron detector**)
    - *Temperature* (Thermometer, calorimeter, temperature gauge)
    - *Chemical* (Breathalyzer, olfactometer, smoke detector)
    - *Biosensors* (Blood glucose biosensor, pulse oximetry, electrocardiograph)

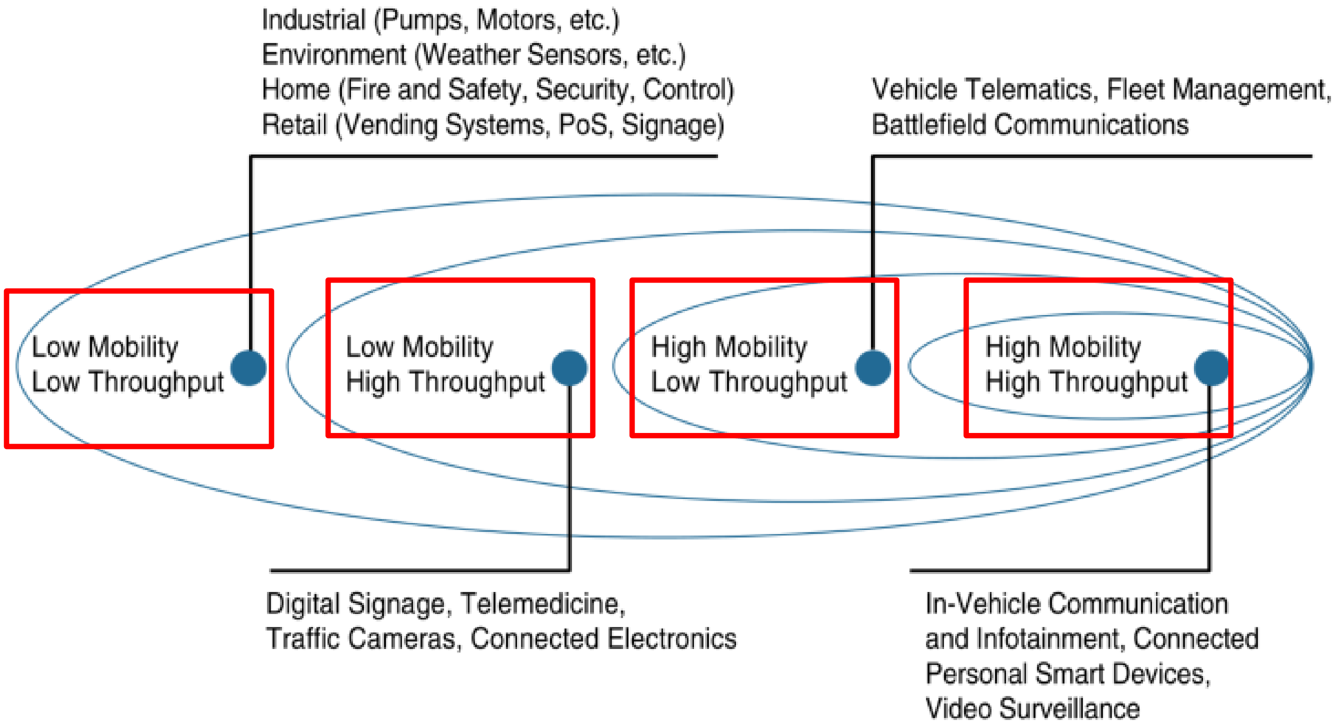






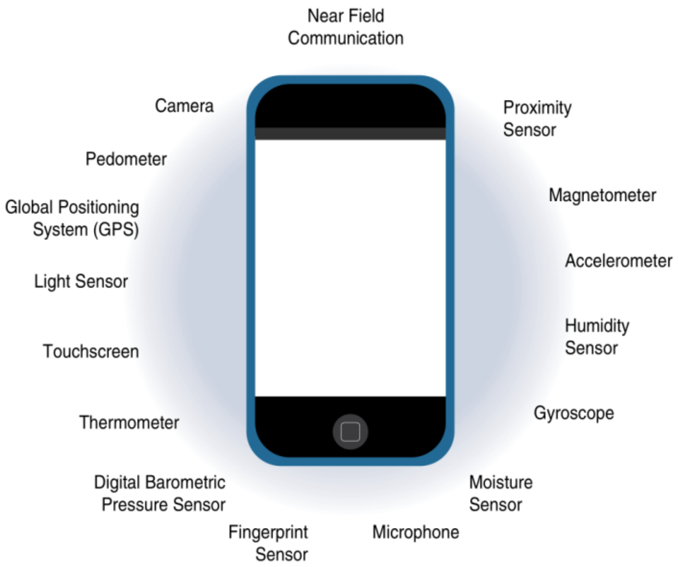



Sensors (4)


Industrial (Pumps, Motors, etc.)
Environment (Weather Sensors, etc.)
Home (Fire and Safety, Security, Control)
Retail (Vending Systems, PoS, Signage)
Vehicle Telematics, Fleet Management,
Battlefield Communications
Low Mobility
Low Throughput
Low Mobility
High Throughput
High Mobility
Low Throughput
High Mobility
High Throughput
Digital Signage, Telemedicine,
Traffic Cameras, Connected Electronics
In-Vehicle Communication
and Infotainment, Connected
Personal Smart Devices,
Video Surveillance

What made smartphones smart?

- Touchscreens, accelerometers, gyroscopes, GPS, cameras, etc ...

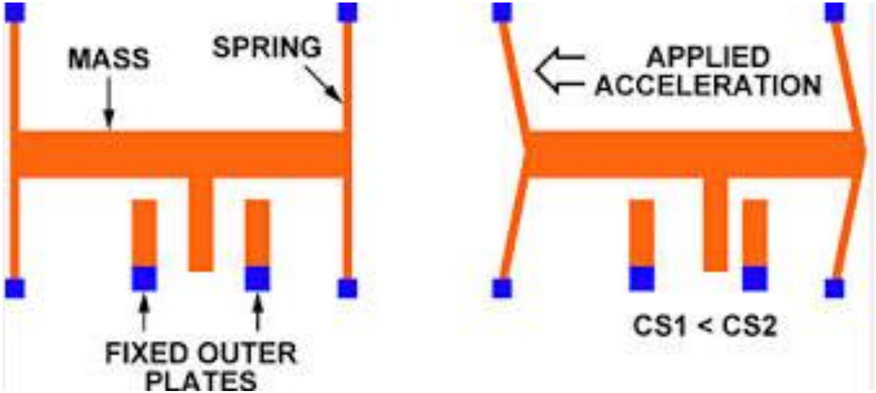


Sensor examples: Distance/range

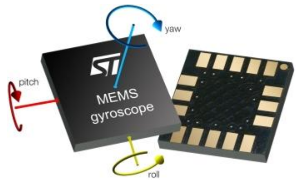
1. **IR sensors**: Contain an infrared emitter, and an infrared detector
   - ➢ Works by emitting a certain amount of infrared light, and seeing how much it gets back
   - ➢ Why infrared ?
     - There are not so many other infrared sources in everyday life that would interfere with this sensor
     - If visible light were used, light bulbs, computer screens, cellphone screens, etc., would all interfere with the depth reading
2. **Ultrasound sensors**: contain a high frequency speaker, and a microphone
   - ➢ Works just like a sonar, emitting a sound, and listening for the echo to determine range
   - ➢ Very high frequency sound, it is practically beyond what humans can hear.
     - Pros: More accurate than IR sensors at slightly longer distance (typically up to several feet)
     - Cons: Almost twice the price

Sensor examples: Accelerometers

- Measure change in velocity in axial dimensions (typically 3 axes)
- How does it work?
  - The “proof mass” shown is allowed to move in a plane.
  - The attached fingers form a capacitor with the two plates around it.
  - The rate of change of the capacities measured and translated into an acceleration



Sensor examples: Gyroscopes



- ➢ Measures orientation
- ➢ How does it work?
  - If an object is moving along one axis, and it is rotated above another, it will feel a coriolis force in the third axial direction
  - A gyroscope will have a mass oscillating back and force along the first axis, and plates on either side of the mass in the third direction (direction of the Coriolis force)
  - When a rotating is detected around the second direction, the capacitance changes

Sensing Properties

Input Range

- ➢ the operating range to which the sensor is sensing **{-20°C to 40°C}**

Output Range

- ➢ range of the output value [0, +5V], [0…255]

Sensitivity

- ➢ How much of a change in input signal is needed for a change in the output signal?

Latency:

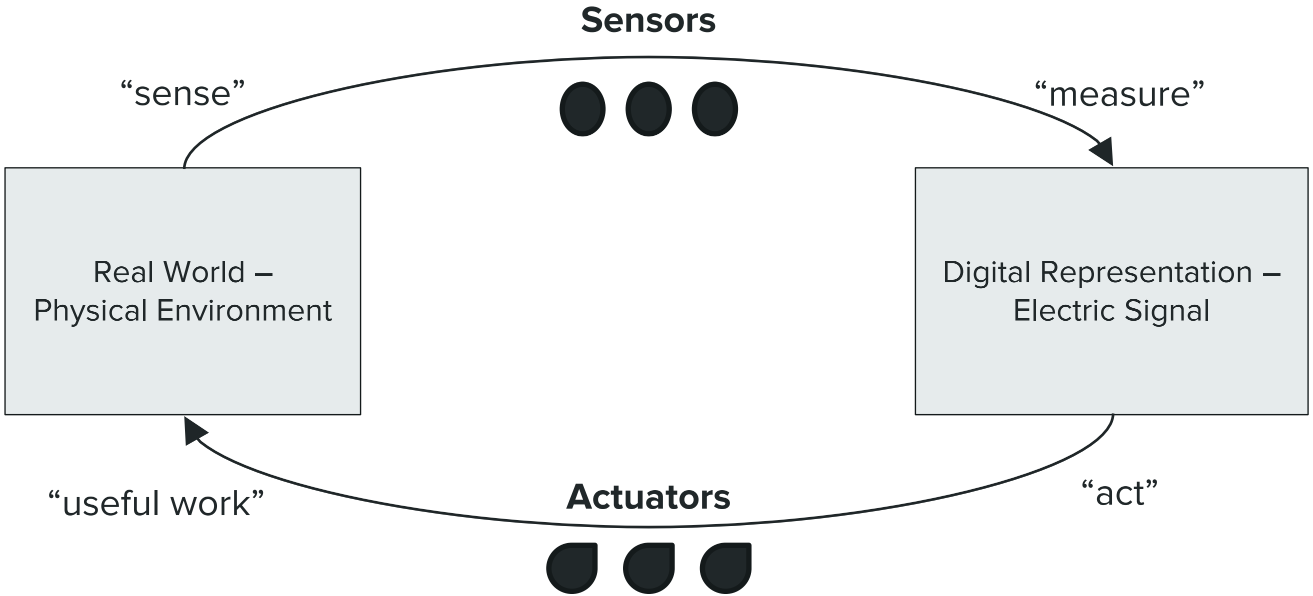
- ➢ Speed with which sensor detects/reacts to change

Stability/Drift:

- ➢ insensitivity to factors other then measured physical quantity

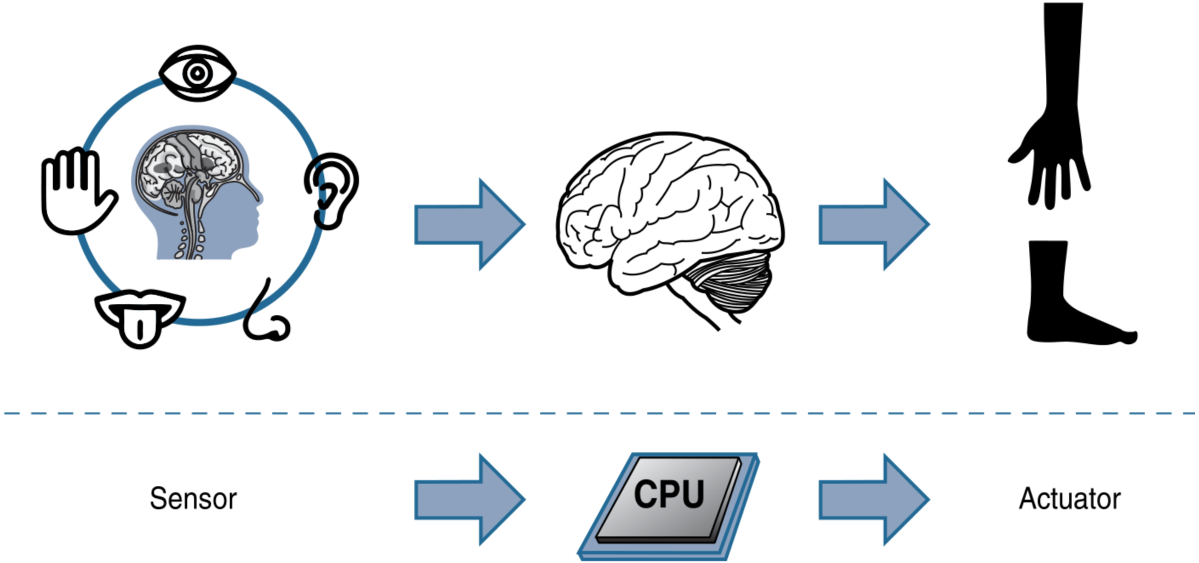
Actuators (1)

➢ Natural complements to sensors



Actuators (2)

- Comparison of Sensor and Actuator Functionality with Humans



Actuators (3) – types

- Actuators also vary greatly in function, size, design
    - *Type of motion* (linear, rotary, one/two/three-axes)
    - *Power* (high power, low power, micro power)
    - *Binary or continuous* (number of stable-state outputs)
    - *Area of application*
    - *Type of energy*

Actuators (4) – by energy types

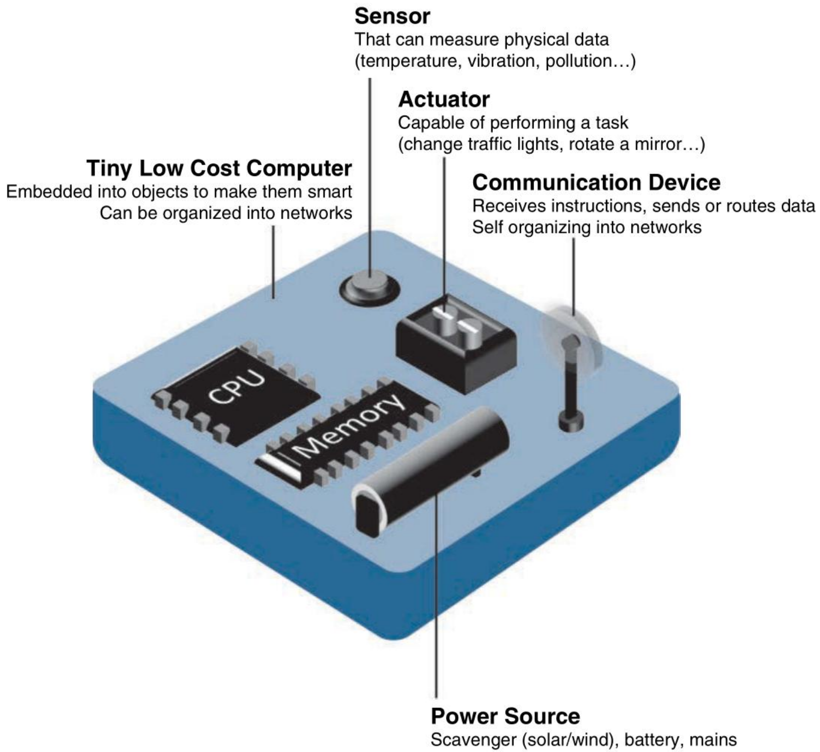
- *Mechanical actuators* (lever, screw jack, hand crank)
- *Electrical actuators* (thyristor, biopolar transistor, diode)
- *Electromechanical actuators* (AC motor, DC motor, step motor)
- *Electromagnetic actuators* (electromagnet, linear solenoid)
- *Hydraulic and pneumatic actuators* (hydraulic cylinder, pneumatic cylinder, piston, pressure control valves, air motors)
- *Smart material actuators* (shape memory alloy (SMA), ion exchange fluid, magnetorestrictive material, bimetallic strip, piezoelectric bimorph)
- *Micro- and nanoactuators* (electrostatic motor, microvalve, comb drive)

Smart Objects (1)

- Building blocks of IoT
- A smart object is a device that has, at a minimum, the following four defining characteristics
  - Processing unit
  - Sensor(s) and/or actuator(s)
  - Communication device
  - Power source

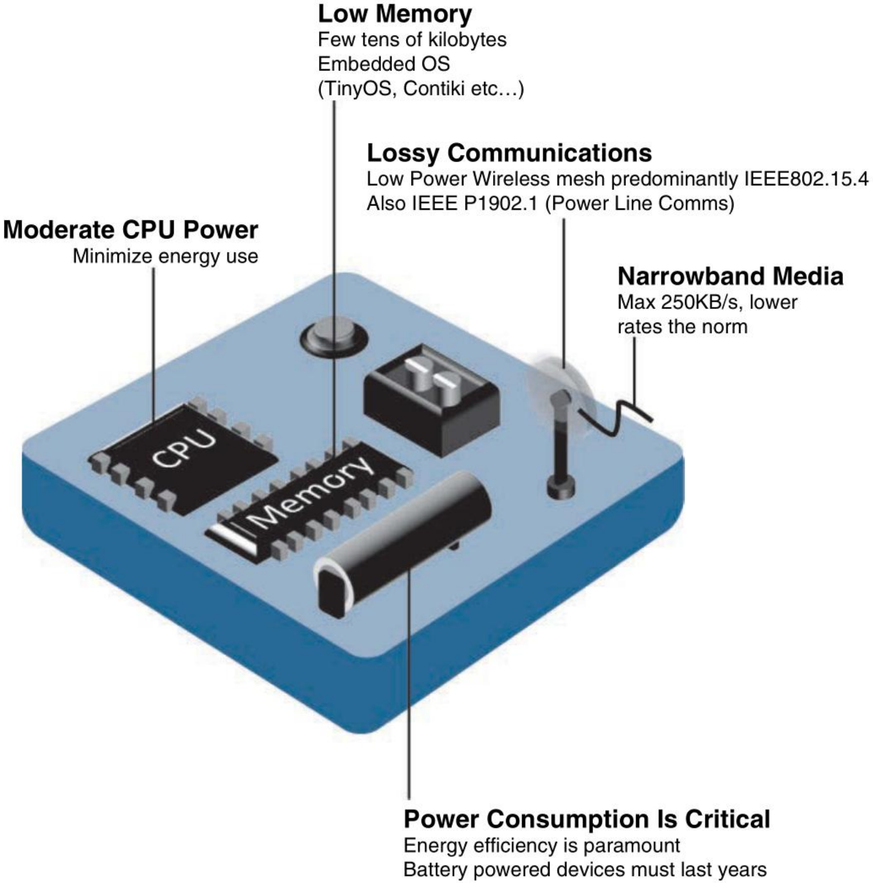
Smart Objects (2)

➢ Able to learn from and interact with the environment



Wireless communication between smart objects

- Constraint nodes



Exercise: Identifying Sensors, Actuators, and Smart Obj.

- **Objective:** Apply your knowledge of IoT components to real-world examples.

Instructions:

1. Form **small groups (2–3 students)**.
2. For each of the following scenarios:
   I. Identify at least **one sensor** involved.
   II. Identify at least **one actuator** that could be part of the system.
   III. Determine if a **smart object** is described, and explain why.

- **Scenarios:**

1. *Smart Home Thermostat*: Automatically adjusts the temperature based on the weather and user preferences.
2. *Smart Irrigation System*: Waters plants based on soil moisture levels and weather forecasts.
3. *Fitness Tracker*: Tracks heart rate and steps, sending the data to a mobile app.
4. *Parking Garage System*: Uses cameras to detect available spaces and displays them on a digital board.

Time: 10 minutes

Tip: Focus on the *input (sensor)*, *output (actuator)*, and *intelligence (smart object)* of the system.

Conclusion

- “Things” in the IoT
- Sensors have properties important for applications and system planning/design
- Actuators are used to optimize the application
- Smart objects are platforms with sensing, actuating, processing and communicating capabilities

Thank you

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