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Principles of IoT and Python Programming

—

G. R. Kanagachidambaresan

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# Internet of Things Using Single Board Computers

## Principles of IoT and Python Programming

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***Internet of Things Using Single Board Computers: Principles of IoT and Python Programming***

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Printed on acid-free paper

*To my family, students, dear friends, and scholars*

*I specially dedicate this to my son, Ananthajith K*

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# About the Author

**G. R. Kanagachidambaresan** completed his PhD in Information and Communication Engineering from Anna University, Chennai, in 2017. He is currently an associate professor in the CSE Department at Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology. He is also a visiting professor at the University of Johannesburg.

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# Preface

The rapid growth of technology and new smart, sustainable development initiatives has made the Internet of Things (IoT) and edge analytics an inevitable platform for all engineering domains. The need for a sophisticated and ambient environment has resulted in an exponential growth in automation and artificial intelligence. The right sensor or actuator, a specific processor, and the correct transmission unit can offer the best solution to any IoT problem. Lightweight machine learning or mathematical logic can bring a good solution to existing smart-city problems.

This book provides detailed information on sensors, their interfacing connections, programming with single-board computers, and creating integrated projects with a combination of sensors, processors, and actuators. A detailed introduction to Python and Arduino-based programming is also discussed to kindle interest in IoT programming. IoT products' wired and wireless connections are discussed, and programming examples are provided.

This is a completely new textbook that reflects recent developments while providing a comprehensive introduction to the fields of IoT, single-board computers, and Python programming. It is aimed at advanced undergraduates as well as researchers and practitioners. This book deals more with electronics and programming than simple text. It best suits outcome-based education systems and can aid industry-ready IoT engineers.

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The original version of this book was revised. A correction to this book is available at https://doi.org/10.1007/978-1-4842-8108-6_11

CHAPTER 1

# An Overview of the Internet of Things (IoT) and Sensors

Recent advancements in single-board computers (SBCs) [16] and boards have made the Internet of Things (IoT) more accessible and easier to use. The complete automation, information analysis from sensor data, and integration of individual components with IoT systems helps to build new Smart environment solutions. The scope of the areas is broadened with IoT components and sensors.

IoT uses existing and emerging technology for event detection and automation. IoT has the advantages of recent software advancements, reducing hardware prices and available technology options. It created a great change in product delivery and services and a major revolution in Industry 4.0. Figure 1-1 illustrates the key features of IoT.


G. R. Kanagachidambaresan, *Internet of Things Using Single Board Computers*, Maker Innovations Series, https://doi.org/10.1007/978-1-4842-8108-6_1

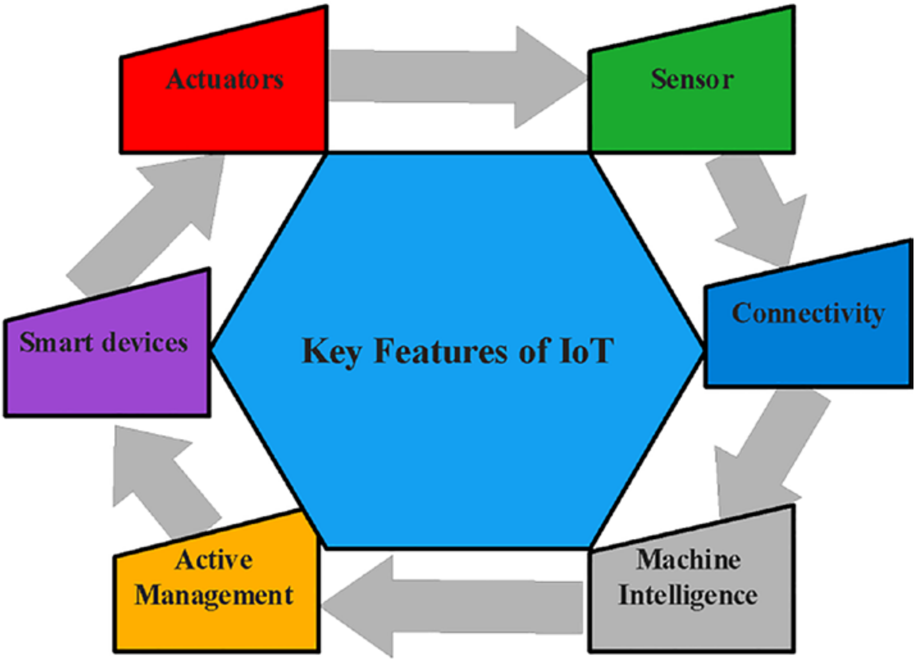


***Figure 1-1.*** *IoT feature and data flow*

## Sensors

Sensors are the main data acquisition and detection system, which converts any physical quantity (i.e., event) into a signal. In some sensors, direct conversion takes place; in others, multiple conversions take place to attain accuracy and quantification. Some of the sensors used in IoT and prototyping are shown in Figure 1-2. Sensors are collectively connected with an A/D converter to convert their signals to digital forms so that a processor understands and can program effectively. Figure 1-2 illustrates sensor classification (mode of operation, signal output, and energy-based).

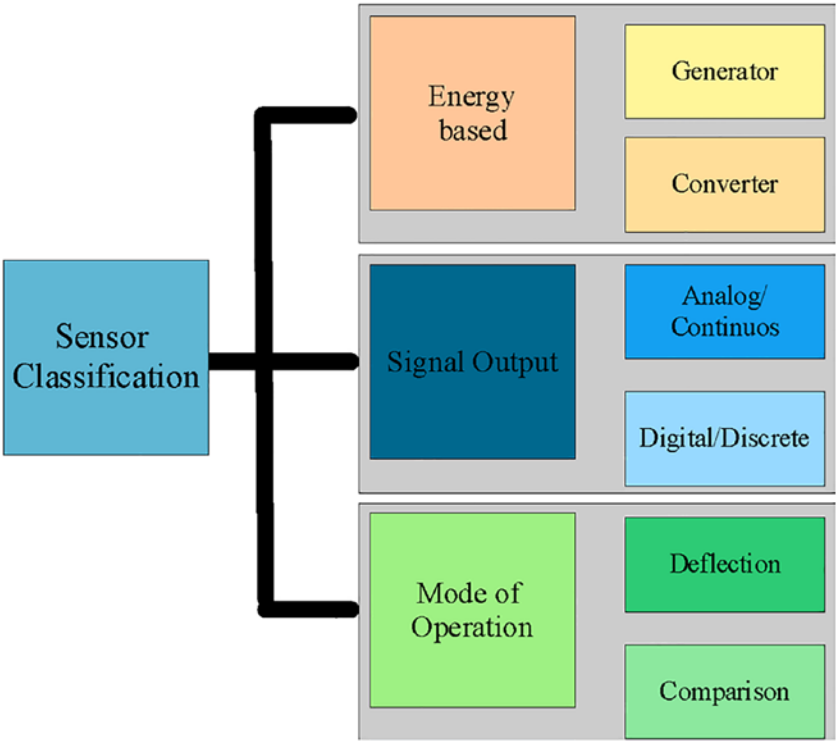


***Figure 1-2.*** *Sensor type classification*

Next, let's further discuss sensor type classification.

# Energy-based

## Generator

Energy generation–based sensors provides conversion energy conversion, like voltage and current, on any physical event. For example, a piezoelectric sensor converts vibration energy to a proportional voltage. The seebeck metal junction converts the change in temperature to proportional energy conversion.

### Conversion

Sensors convert one mode of physical quantity to another; for example, an anemometer converts air velocity to rotational motion, which is further converted to electrical voltage for measurement. These sensors are operated in a proportional zone for calibration and stable operation. Most sensors provide linear data conversion.

## Signal Output

### Analog

Sensors such as anemometers provide analog conversion of data. Analog signal from annemometer is converted to digital data with the help of an analog-to-digital converter. The sensor’s frequency of operation should be far greater than the frequency of the physical quantity to get clear information after digital conversion.

### Discrete

Cameras and tile-based sensors provide discrete and digital information directly to the processor. This makes the sensor easy to integrate with any digital processor.

## Mode of Operation

Sensors are deflection- or comparison-based. Deflection happens when sensing a physical event. This is normally an angular-based movement between two points. Comparison-based meters normally work with standard available data. GPS sensors provide comparison-based sensing.

- Deflection (e.g., voltage meters and current meters)
- Comparison (e.g., GPS sensors)

## Electronic Sensors

Figure 1-3 illustrates sensor classification based on the field of operation, such as mechanical, optical, electrical, acoustic, thermal, chemical, radiation, biological, and magnetic.

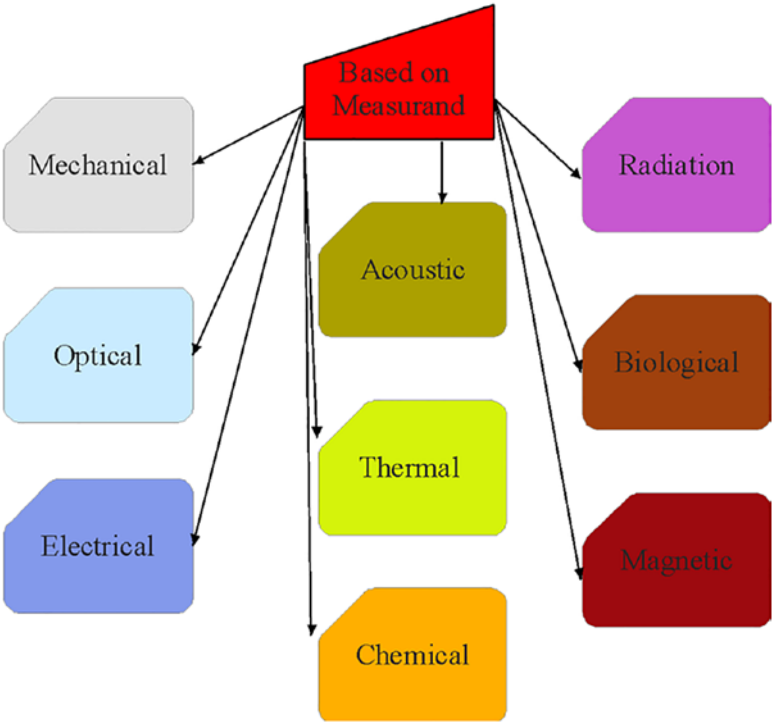


***Figure 1-3.*** *Sensor classification based on measurand*

## Mechanical

- Linear and angular position
- Velocity of the subject
- Acceleration

- Force
- Viscosity, rigidness, and roughness
- Pressure and stress
- Strain
- Mass and density measurement

## Optical

- Wave velocity
- Polarization and spectrum
- Wave amplitude

## Electrical

- Conductivity
- Potential difference
- Charge and current density
- Field

## Thermal

- Heat flux
- Thermal conductivity

## Chemical

- States and identifies
- Color change
- Change in voltage

### Radiation

- Energy
- Intensity

### Biological

- Mass
- Concentration
- States
- Magnetic
- Magnetic field
- Magnetic flux
- Permeability

## Connectivity

Figure 1-4 illustrates the connectivity features of IoT communication.

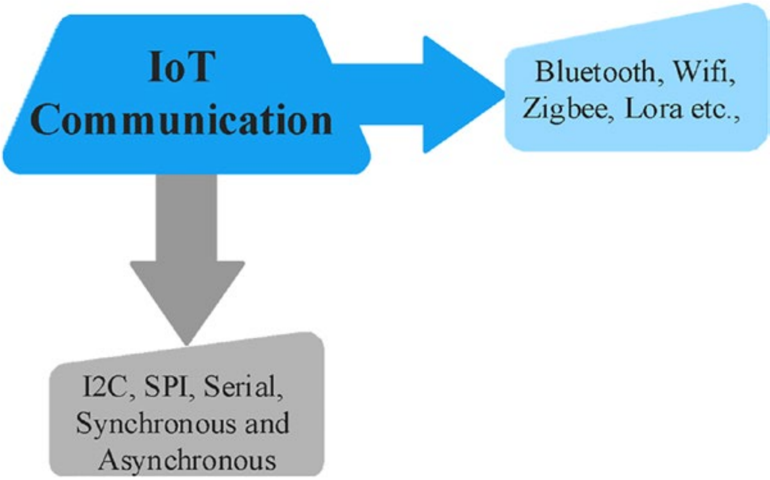


***Figure 1-4.*** *IoT connectivity features*

Bluetooth Low Energy, Zigbee, LoRa, and Wi-Fi are the most common types of connectivity in an IoT environment. I2C, SPI, and Rx-Tx serial communication protocols are examples of wired connectivity.

## Bluetooth

Bluetooth network technology creates a personal area network (PAN) by wirelessly connecting mobile devices over a short distance. The Bluetooth architecture has its own independent model with a stack of protocols; it does not follow the standard OSI or TCP/IP models.

## Zigbee

The Zigbee 3.0 protocol [1] is an IEEE 802.15.4 specification that supports a 2.4 GHz frequency band. The following are some of the features of Zigbee 3.0.

- Low power: Devices that comply with Zigbee 3.0 consume less power and transmit data at a slower rate. For IoT devices, long-lasting batteries are required. As a result, the Internet of Things (IoT) network extensively uses this standard.
- Reliable and robust: The mesh topology of the Zigbee 3.0 network eliminates single points of failure and ensures packet delivery reliability.
- Scalable: Devices can be added to a Zigbee 3.0 network anytime.
- It is a secure network because it employs AES-128 encryption.
- Global standard: Zigbee 3.0 devices use the 2.4 GHz frequency band, which is widely used worldwide. As a result, it has become the industry standard around the world.

## Wi-Fi

Wi-Fi [2] is a technology that transfers data through radio waves that can make small gadgets exchange data connected within a small router. Wi-Fi uses the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards for effective data transmission.

IEEE 802.11 devices have the primary benefit of making it easier to deploy local area networks (LANs) at a lower cost. They can host wireless LANs in outdoor areas and airports, where running cables to every device isn't practical.

## LoRa

LoRa [3] is a long-range wireless communication technology derived from the CSS chirp-based spread spectrum. The chirp pulses communicate information, similar to BATS communication.

## Wired Communication

### I²C

I²C (Inter-Integrated Circuit) [4] is a two-wired communication protocol (see Figure 1-5). It is a bus interface, serial communication protocol built into devices. It has recently become a popular protocol for short-distance communication.

Only two bidirectional open-drain lines—SDA (Serial Data) and SCL (Serial Clock)—are used for data communication. Both lines are cranked up. The SDA pin sends and receives data. SCL carries the clock signal.

I2C has two modes of operation: master and slave. Master mode is the most advanced mode.

Slave mode obeys the command from the master and transmits or receives data accordingly.

Each clock's high to low pulse on the SCL line synchronizes each data bit transferred on the SDA line. Figure 1-5 shows I²C communication protocols.

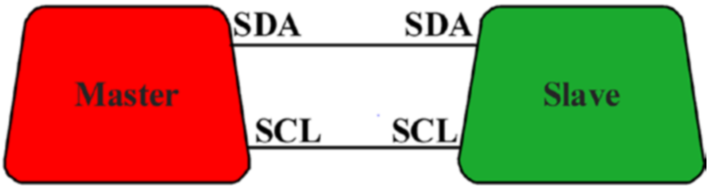


***Figure 1-5.*** *I²C communication protocols*

## SPI

The data communication module uses SDA and SCL dual connection lines. SDA receives and transmits data. Serial Peripheral Interface (SPI) communication is mainly used by components such as RTC, A-to-D converters, and other computer peripherals. SPI [5] communication uses a full duplex synchronous communication protocol that works in serial mode between the master and slave devices. Figure 1-6 illustrates SPI communication protocols.

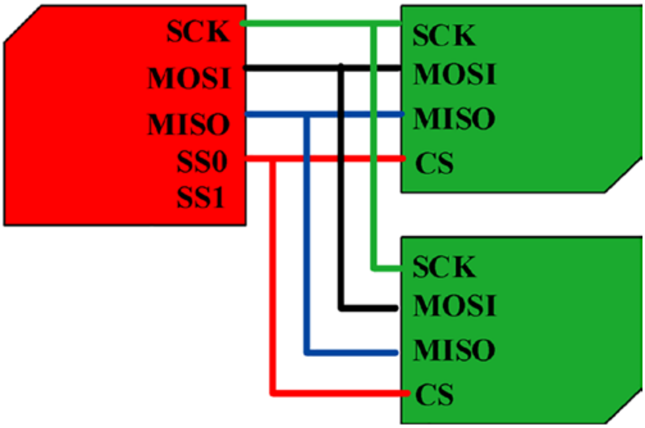


***Figure 1-6.*** *SPI communication protocols*

## Serial Communication

Serial communication is a straightforward and dependable way to send data over long distances. RS-232 is a widely used serial communication protocol. The data in this standard is sent in serial format at a preset speed (called a *baud rate/number*) of bits communicated between the sender and receiver. Common baud rates are 4800, 9600, 19200, and 38400. Figure 1-7 shows the connection diagram for the UART communication scheme.

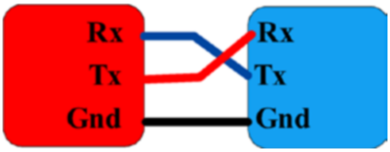


***Figure 1-7.*** *UART data communication*

## Machine Intelligence

Machine intelligence [14] attempts to program a computer to perform previously human-only tasks. In general, the learning process in intelligent machines entails gathering information about their environment, deploying that information to build knowledge about it, and then generalizing that knowledge base to deal with environmental uncertainty.

Two machine intelligence techniques—imitation learning and reinforcement learning—have been developed to help machines learn. The learning algorithms are opted based on consideration of tasks and their characteristics. Intelligent systems are an option to collect data from the agents and acquire knowledge about its surrounding, and the computation is adapted for the environment. To maintain control over a society of autonomous agents, the agents' learning process requires a self-organizing mechanism. It should be noted that imbuing intelligent machines with the capacity to learn is a difficult task; however, the capacity to learn is what defines a machine as intelligent. Figure 1-8 illustrates machine learning classification based on input data.

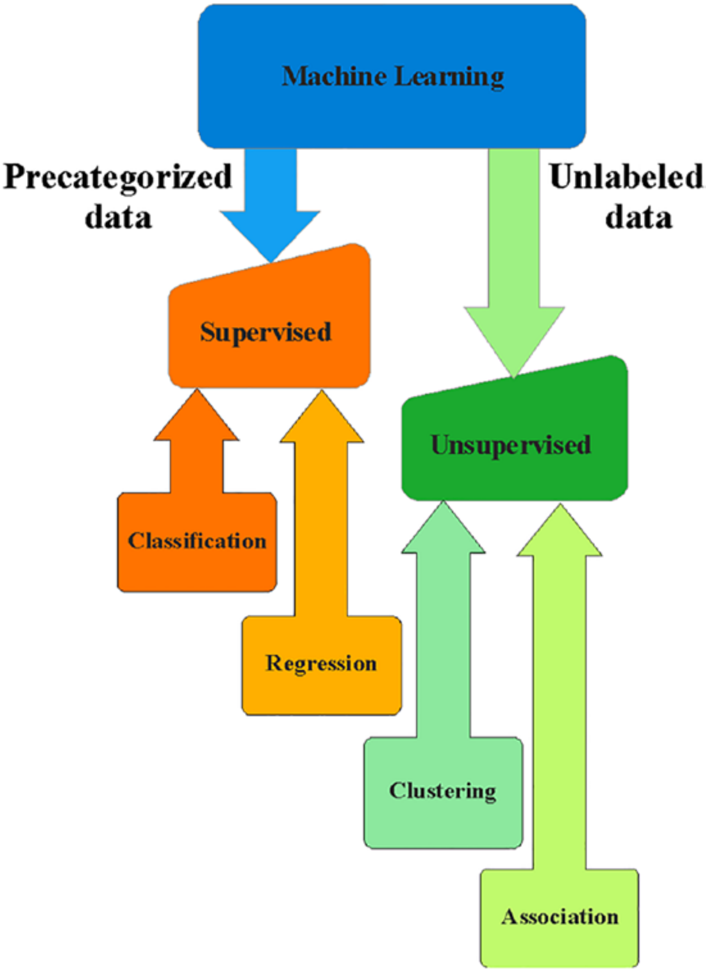


***Figure 1-8.*** *Classical machine learning domains*

The supervised learning module predicts category (classification module) and number (regression module). Unsupervised learning provides clustering, dimension reduction, and association modules.