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A Comprehensive Study of IoT Sensors and Actuators

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Abstract: The Internet of Things (IoT) is a cutting-edge technology. By building a smart environment around us with trillions of sensors and actuators, it is revolutionising our world. A unified operating picture can be created using shared information from ubiquitous sensing capabilities. Recently, sensors have been thought of as a very promising aspect of scientific study. IoT-based sensors have become a significant role because of their widespread usage and functionality. Sensors are frequently employed in the industrial internet to monitor manufacturing processes as well as our physical and environmental health, as well as the security of our homes. Earlier, businesses and organisations used a variety of sensors, but the advent of the Internet of Things has catapulted sensor development to an entirely new level. Various IoT sensors and actuators utilized in them is presented in this paper together with a number of IoT sensors.

Keywords: Internet of Things (IoT); GPS; Sensors; Bluetooth Low Energy (BLE)

1. INTRODUCTION

IoT stands for the "Internet of Things." It refers to the interconnected network of physical devices, vehicles, buildings, and other objects that are embedded with sensors, software, and other technologies that enable them to collect and exchange data [1]. These devices can range from simple sensors and actuators to complex machinery and systems, and they can be connected to the internet or other networks to enable remote control, monitoring, and data analysis [2].

The concept of IoT is based on the idea that by connecting and integrating these physical devices and systems, we can create a more efficient and intelligent environment that can improve our lives in a variety of ways [3]. For example, IoT technology can be used to monitor and control energy usage in homes and buildings, track and optimize traffic flows on roads and highways, and improve the quality and efficiency of manufacturing processes.

IoT is a rapidly growing field that is expected to have a significant impact on many industries and aspects of our daily lives [4].

The idea of connected devices and machine-to-machine communication can be traced back to the early days of the internet in the 1990s. However, the term "Internet of Things" was first coined in 1999 by British technology pioneer Kevin Ashton, who was part of a team that was exploring the use of RFID (radio-frequency identification) technology to track inventory in supply chains [5].

In the years that followed, advances in wireless communication, sensors, and computing technologies made it possible to connect a wider range of devices and objects to the internet. The first practical applications of IoT technology were in the fields of industrial automation and control, where sensors and other devices were used to monitor and optimize production processes. In the 2000s, the emergence of smart phones and other mobile devices, along with the growing availability of wireless networks, paved the way for consumer-oriented IoT applications. Smart home devices such as thermostats, lighting systems, and security cameras became increasingly popular, and wearable devices such as fitness trackers and smart watches began to gain traction [1]. The objective of this paper is to give introduction of IoT, Sensors and Actuators in IoT.

2. FUNDAMENTAL COMPONENTS OF IOT

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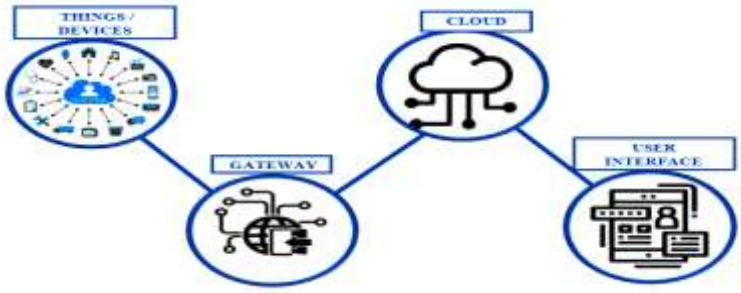

2.1 THINGS / DEVICES

These are fitted with sensors and actuators. Sensors and actuators are essential components of IoT (Internet of Things) systems that enable devices to interact with the physical world and respond to changing conditions. As the number of IoT devices continues to grow, sensors and actuators will play an increasingly important role in enabling smart, connected systems that are capable of collecting and analyzing data, making decisions, and taking action in real-time.

In IoT systems, sensors and actuators work together to collect data, analyze it, and take action based on predefined rules or algorithms [3]. For example, a temperature sensor may detect a temperature that's too high and send a signal to an actuator, such as a fan, to turn on and cool down the environment.

2.2 GATEWAY

Data from the sensors is sent to the Gateway, where some form of pre-processing is also carried out. Additionally, it adds a layer of security to the network and the data being transmitted. A gateway is a critical component of an IoT system that enables communication between IoT devices and the cloud or other external networks [3]. A gateway acts as a bridge between the local IoT network and the internet, allowing devices to send and receive data to and from cloud-based services, applications, and databases. Gateways can be physical devices or software-based virtual gateways, and they typically include hardware components such as processors, memory, storage, and communication interfaces such as Wi-Fi, Bluetooth, Zigbee, or cellular networks. Gateways play a critical role in enabling communication between IoT devices and external networks, improving system performance, and enhancing security [6].

2.3 CLOUD

The Internet of Things generates enormous amounts of data from devices, applications, and users that must be effectively managed. IoT cloud provides capabilities to quickly gather, manage, process, and store massive amounts of data. These data are easily accessible remotely, allowing businesses and services to take important decisions as needed. IoT cloud is a sophisticated, high-performance network of servers designed to handle traffic management, high-speed data processing of numerous devices, and accurate data analysis [3].

2.4 USER INTERFACE

The part of the Internet of Things system that users can see and touch is called the user interface. Designers must ensure a well-designed user interface to require the least amount of work from users and promote more interactions. In the highly competitive market of today, user interface design is more important. If new technology is user-friendly and compliant/ with connectivity standards, users will be interested in purchasing smart gadgets [3]. In order to encourage more interactions, developers must offer a well-designed user interface that needs little effort from consumers.

3. SENSORS

Sensors are devices that detect and measure physical parameters, such as temperature, humidity, pressure, and motion, while actuators are devices that control physical processes, such as turning a motor or opening a valve [7]. Together, sensors and actuators enable IoT devices to collect data, make decisions, and take actions based on real-world conditions. Sensors are typically connected to IoT devices through wired or wireless interfaces and can be either analog or digital. Analog sensors measure continuous physical signals, such as voltage or current, and convert them into a digital signal that can be processed by a microcontroller or processor [8]. Digital sensors, on the other hand, generate digital signals directly and do not require analog-to-digital conversion.

3.1 TEMPERATURE SENSOR

The term "Temperature Sensor" refers to a device used to measure the amount of heat energy that enables the user to detect a physical change in temperature from a specific source and translates the data for a device or user [9]. Prior to a

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few years ago, the majority of their applications were for controlling air conditioning, refrigerators, and other environmental control devices. However, with the emergence of the Internet of Things, they have discovered their place in the manufacturing, agricultural, and healthcare sectors [14]. Numerous machines in the manufacturing process require a particular environment temperature as well as device temperature [13]. Thermocouples, resistor temperature detectors (RTD), thermistors, IC (Semiconductor), infrared sensors are some sub-categories of temperature sensors.

3.2 HUMIDITY SENSOR

The amount of water vapour in an environment made up of air or other gases is known as humidity [9]. The phrases "Relative Humidity (RH)" are most frequently used. Since many manufacturing processes demand ideal working conditions, these sensors are typically used in conjunction with temperature sensors [12]. By monitoring the humidity, you can make sure that everything goes as planned. If there is a sudden shift, action may be taken right away because sensors pick up the change relatively immediately [11].

3.3 PROXIMITY SENSOR

A device that, without coming into touch with it, detects the presence or absence of adjacent objects or their characteristics and turns that information into a signal that a user or a basic electrical instrument can easily interpret [15]. Due to its ability to detect mobility and the relationship between a customer and a product they may be interested in, proximity sensors are widely used in the retail sector [9]. The proximity sensor alerts you to an obstruction when you are in reverse as you are reversing your car [11].

Inductive Sensors, capacitive sensors, photoelectric sensors, ultrasonic sensors are some sub-categories of proximity sensors.

3.4 PRESSURE SENSOR

A device that detects pressure and turns it into an electric signal is called a pressure sensor. Here, the amount is influenced by the amount of pressure used [7]. There are several gadgets that depend on liquid pressure or other types of pressure. IoT systems that monitor pressure-driven systems and devices can be built using these sensors. The device alerts the system administrator to any deviations from the normal pressure range and any issues that need to be corrected [11].

3.5 WATER QUALITY SENSOR

In water distribution systems, water quality sensors are generally used to detect the water quality and monitor ions [9]. Practically everywhere uses water. These sensors are crucial because they keep track of the water's purity for various uses [12][16]. Chlorine residual sensor, total organic carbon sensor, turbidity sensor, conductivity sensor, pH sensor, oxygen-reduction potential sensor are some sub-categories of water quality sensors.

3.6 GAS SENSOR

Similar to chemical sensors, gas sensors are used to monitor changes in air quality and identify the presence of different gases [13]. Similar to chemical sensors, they are employed in a variety of sectors including manufacturing, agriculture, and health to monitor air quality, identify toxic or combustible gases, monitor hazardous gases in coal mines, the oil and gas industry, conduct chemical laboratory research, and manufacture goods such as paints, plastics, rubber, pharmaceuticals, and petrochemicals [10].

Breathalyzer, hydrogen sensor, oxygen sensor, gas detector etc. are some sub-categories of gas sensors.

3.7 LEVEL SENSOR

Level sensors are a type of sensor that measure the amount or level of fluids, liquids, or other substances flowing through an open or closed system. Level sensors are utilised in a variety of industries, just like IR sensors [16]. They are employed by companies that deal with liquid materials and are primarily renowned for gauging fuel levels. For instance, these sensors are used by the recycling sector, the juice and alcohol industries, and others to count their liquid assets. The best applications for level sensors include measuring fuel and liquid levels in open or closed containers, monitoring sea level and tsunami warning systems, water reservoirs, medical devices, compressors, hydraulic reservoirs, machine tools, processing of beverages and pharmaceuticals, and high- and low-level detection, among others [17].

3.8 MOTION SENSOR

A motion detector is an electrical device that detects movement (motion) in a specific region and converts motion (motion of any object or motion of people) into an electric signal [9]. In the security sector, motion detection is significant. Businesses use these sensors in locations where there should never be any movement noticed, and it is simple to detect anyone's presence when these sensors are deployed [11]. These sensors will primarily be used by

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software development companies or IoT businesses for intrusion detection systems, automatic door controls, boom barriers, smart cameras (i.e. motion-based capture/video recording), toll plaza, automatic parking systems, automated sinks/toilet flushers, hand dryers, energy management systems (i.e. automated lighting, AC, fan, appliances control), etc [14].

3.9 ACCELEROMETER SENSOR

A transducer called an accelerometer is used to measure the actual, quantifiable acceleration that an object experiences as a result of inertial forces and transforms the mechanical motion into an electrical output [4]. It is described as the speed at which velocity varies with regard to time. Today, these sensors can be found in millions of gadgets, including smart phones. Their applications include the general detection of acceleration, tilting, and vibration. This is perfect for employing a smart pedometer or for keeping an eye on your driving fleet. As the sensor can alert the system if an object that should remain stationary is moved, it is sometimes used as a form of anti-theft protection. They are frequently utilised in things like cellular and media devices, vibration measurement, automobile control and detection, free fall detection, aircraft and aviation sectors, movement detection, sports academies/athletes behavior monitoring, consumer electronics, industrial & construction sites, etc [12].

Hall-effect accelerometers, Capacitive accelerometers, Piezoelectric accelerometers are various kinds of accelerometers mainly used in IoT projects.

3.10 LDR SENSOR

An electronic component called an LDR sensor, sometimes referred to as a Light-Dependent Resistor sensor or a photoresistor sensor, is able to measure the amount of light present in the immediate environment [18]. LDR sensors are constructed from a semiconductor material whose resistance lowers with increasing illumination. Due to this characteristic, LDR sensors are helpful in a variety of applications where light level sensing is required, including camera sensors, security systems, and streetlights [14].

An LDR sensor's resistance drops and its current flow increases when it is exposed to light. The intensity of the light can be measured using this change in resistance [16].

3.11 RAIN DROP SENSOR

A sensor used to identify the presence of rain or other types of precipitation is called a raindrop sensor. On a printed circuit board (PCB) or another substrate material, it is often made up of two conductive wires that are positioned closely together. Droplets of water create a conductive route between the two wires when they touch the sensor, allowing current to flow [16]. The sensor then measures this variation in resistance and uses it to determine whether or not it is raining.

3.12 SOIL MOISTURE SENSOR

An electronic instrument that gauges the moisture content of soil is called a soil moisture sensor. A probe that is put into the soil to detect the electrical conductivity between two electrodes normally makes up the sensor [19]. In contrast to moist soil, which has a low electrical resistance, dry soil has a high electrical resistance. The sensor can gauge the soil's moisture content by measuring the resistance between the electrodes.

Some soil moisture monitors come with temperature sensors as well, which can be used to help choose when to sow and harvest crops [16].

3.13 SOUND DETECTION SENSOR

An electronic device that can identify the presence and volume of sound in a space is a sound detection sensor. A microphone or a piezoelectric sensor, which can translate sound waves into electrical signals that can be processed and evaluated by a microcontroller or other electronic equipment, often makes up these sensors [11].

Machine learning algorithms can be used in conjunction with sound detection sensors to categorize various sound kinds, such as speech, music, and background noise [16].

3.14 HEART RATE SENSOR

With the use of optical sensors and LED lights, the heart rate sensor measures the heartbeat. This smartphone sensor measures the light waves that are reflected on the skin after an LED light is directed in its direction. When there is a pulse, there is a change in the light's intensity [21]. By analysing variations in light intensity between brief pulses of the blood vessels, heart beat can be calculated [16]. This technique is often used in fitness and health apps to determine heart rate.

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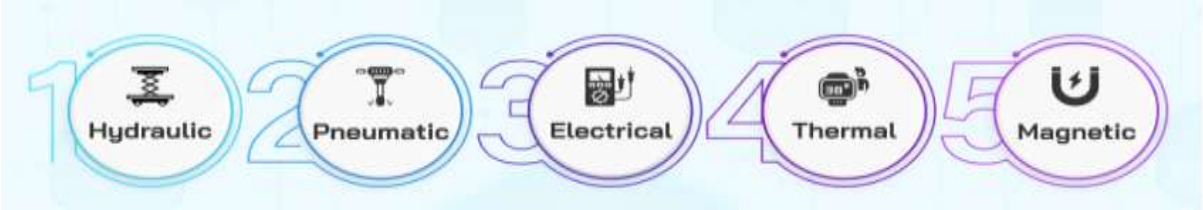
3.15 GPS

GPS stands for Global Positioning System, and it is used to determine the exact UTC time and latitude and longitude of any location on Earth. In our project, the location of accidents is tracked using a GPS module [20]. Every second, this device receives the coordinates from the satellite. The real-time position tracking data sent by the GPS module is in NMEA format, as can be seen in the screenshot below [14]. There are multiple sentences in the NMEA format, but we only need one giving the link and additional information.

4. ACTUATORS

In IoT (Internet of Things) systems, actuators are a particular kind of device that are used to regulate physical processes based on information gathered from sensors. Electrical impulses can be translated into physical movements, such driving a motor or opening a valve, using actuators [9][14]. Devices in IoT systems can communicate with the physical world and react to changing circumstances by using actuators. Actuators are connected to a system's output. After receiving an electrical signal as input, it outputs mechanical movement. It transmits information to the outer environment after receiving instructions or input from a system or signal conditioning apparatus [22].

4.1 TYPES OF ACTUATORS



4.1.1 HYDRAULIC ACTUATORS

These actuators perform mechanical actions by utilizing hydraulic energy. Cylinder or fluid motors are frequently used to power these actuators [9][14]. According to the standards and recommendations, the mechanical motion is converted into oscillatory, linear, or rotational motion [24].

4.1.2 PNEUMATIC ACTUATORS

The mechanical energy of gas or compressed air is converted into energy that controls one or more components using pneumatic actuators [14]. Machines can produce either linear or rotary movements, depending on their design. The external compressive force that is stored within a compressive gas is used to force the piston to create pressure inside a hollow cylinder. As a result, a force that is produced in response to the piston's pressure propels the load in that direction [9]. The fact that they are sturdy, last a long time, and need little upkeep is an advantage. Because air can endure extremely high temperatures, using it is safer [23].

4.1.3 ELECTRICAL ACTUATORS

With the help of an electric motor, electric actuators are electromechanical devices that can perform actions like clamping that require force [9]. Electrical energy is transformed into mechanical torque by the electric motor. They offer clean, safe, and simple to use movements with accurate and fluid motion control [23]. Electric actuators are extremely energy efficient and have a very long lifespan [14]. It is easy to use and quiet when in use. With these, high precision can be reached. Electrical actuators have the drawback of only being usable in regions with certain climatic conditions [24].

4.1.4 THERMAL ACTUATORS

These actuators are used in many different devices, including thermostats, thermal bypass valves, thermostatic mixing valves, balancing valves, and many more [14]. Thermal actuators make advantage of the basic principles of thermal expansion. They generate mechanical motions using thermal energy [23]. A typical thermal actuator consists of a temperature-sensing material sealed by a diaphragm that presses against a moving piston [9]. The amount that the temperature-sensing material expands or contracts, which moves the piston, depends on the device's temperature [4].

4.1.5 MAGNETIC ACTUATORS

Magnetic actuators use magnetic forces to move items [4]. The majority of magnetic actuators are built on the Lorentz Force equation [9]. The three types of magnetic actuators that may generate magnetic and repulsive forces are moving magnet actuators, moving coil actuators, and moving iron actuators.

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5. CONCLUSION

The Internet of Things (IoT), which is making our surrounds smarter, is causing a transformation in our world. Any IoT-based smart application needs sensors to be automated in order for the program to respond intelligently and automatically. Numerous IoT sensor and actuator types are described in this study. IoT sensor deployment can help the health, water, transportation, home appliances, garbage, agricultural, cattle, and other industries. IoT uses a variety of sensors that can intelligently and remotely communicate with one another in any given smart application. We began this article with reviewing the history of the Internet of Things, followed by a discussion of various IoT sensor types, a look at IoT actuators, and a table of IoT applications and sensor types.

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