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IoT-Enabled Smart Agriculture Powered By Microcontroller: A Review

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ABSTRACT: Agriculture is critical to the growth of an agricultural country. Many industries, including agricultural, have been altered as a result of the fast rise of Internet of Things-based technology. In India, farming employs over 70% of the people and generates one-third of the nation's capital. Agriculture-related issues have traditionally hampered the country's progress. The only answer to this challenge is smart agriculture, which involves upgrading conventional agricultural processes. Solutions based on IoT are being developed to autonomously manage and monitor agricultural crops with minimum human intervention. Many elements of technology engaged in the realm of IoT in agriculture are covered in this article. It describes the essential components of IoT-based smart farming. Farmers benefit from IoT-based Agriculture by collecting live knowledge (Temperature, Soil Moisture, and Humidity) of agricultural data. These real-time measurements enable farmers to experiment with new agricultural techniques in order to boost average crop yields as well as plant quality. All of these actions will be controlled by any remote smart device or computer linked to the Internet, and they will be carried out by connecting sensors, Wi-Fi or ZigBee modules, cameras, and actuators with a Raspberry Pi and a microcontroller.

KEYWORDS: Precision farming, Smart Greenhouses, Internet-of-Things (IoTs), microcontroller, GSM, Wi-Fi, Bluetooth, ZigBee, sensors (Humidity, Temperature).

I. INTRODUCTION

Agriculture is one of the oldest sciences, having evolved alongside human civilization since the time of Mohenjo-Daro and other ancient civilizations [1]. Agriculture accounts for around sixteen percent (16%) of overall GDP in India and ten percent (10%) of total exports [2]. According to projected numbers, the world population would reach 9.8 billion in 2050, representing a 25% increase over the current amount. Almost the whole population increase predicted is expected to occur in emerging countries. On the other hand, the trend of urbanization is expected to intensify, with over 70% of the world's population expected to be urban by 2050 (now 49%) [3]. To meet the requirements of an ever-increasing population, farmers have begun to employ different agricultural techniques, fertilizers and pesticides, hybrid seed, and so on, in order to increase production rates. However, it was shown that the yield rate did not improve significantly. It is even decreasing in certain locations. It might be due to fertilizer overuse, less arable land, agricultural land fragmentation, agricultural indebtedness, water waste, low soil fertility, climatic change or illnesses, and so on [5].
Agriculture encompasses a range of operations, from field ploughing to crop harvesting. This also depends on other criteria, some of which are within human control while some others are under natural influence. As a result, it is a field full of surprises and secrets that have yet to be discovered. Rain, humidity, soil fertility, and a variety of other meteorological variables and soil qualities are among the different contributors [1]. Farmers can take action rapidly by using GSM/Wi-Fi/Bluetooth/ZigBee technologies, such as sensors. They can make important crop decisions depending on weather, moisture, and humidity levels, as well as soil chemical composition. Agriculture will benefit greatly from technological development. Cultivation will be difficult in a new agricultural location without knowledge of or monitoring of the critical soil properties, resulting in financial losses for farmers [4]. Agricultural characteristics such as soil moisture, humidity, and temperature are continually monitored, and the collected data is sent into a microcontroller. The microcontroller now displays the real-time data of atmospheric conditions on an LCD (Liquid Crystal Display) within the farm. Data is sent to the central unit in real time through a wireless device [5].

IoT Agricultural Application Domains
A variety of IoT agriculture applications are being employed to provide more effective resources for agricultural productivity. Precision farming, livestock monitoring, greenhouse monitoring, and agricultural drones are the primary fields of IoT agriculture applications. Various sorts of agricultural applications are discussed in the following sections [19].

1. **Precision Farming Using Sensors:** Knowing the capabilities of the soil, the nutrients necessary for plant development, and the quantity of moisture necessary in the soil is the most significant aspect of agriculture.

Agricultural sensors are designed to meet these needs. Their major task is to gather data from the beginning of the sowing season until the end of harvesting. Sensors are available for a variety of applications, including CO2 content, NPK content, air temperature, solar radiation, soil mapping etc. The combined data from each of these sensors is utilized for direct analysis of which sort of crop to plant on which portion of the field, how much and what type of fertilizer is needed, what sort of irrigation and how much water is needed, early detection of crop illnesses, and much more. Sensors can be mounted on vehicles, drones the ground, or at a higher height, depending on their intended use.

2. **Smart Greenhouses:** In greenhouses, IoT is utilized to monitor the climate within the greenhouses, assess plant development, plant needs, light level, humidity, and temperature, all without the need for human interaction. Greenhouses are mostly maintained using cloud servers that employ real-time data.
3. **Livestock Monitoring:** The expense of keeping livestock is high, and Internet of things makes it easier. Owners may track their cow's exact position, growth rate, potential illnesses, daily food, water, and nutrition requirements, sleep cycles, and distinguish healthy from unwell calves. Poultry farming, apiculture, and pisciculture may all benefit from the same technology. This saves a lot of money by requiring very little labor.
4. **Farm Management Systems:**IoT is used to handle storage, sales, shipping and maintenance, purchases, and waste management, among other things. Using their cellphones, the farm owner may readily access all of this information in one spot [6].

II. WORKING PRINCIPLE

The transmitter and receiver sections are the two main aspects of the system. Sensor circuit, microcontroller unit, display unit, and GSM/Wi-Fi/Bluetooth/ZigBee module are the key components of the transmitter section. Temperature, pressure, and relative humidity sensors are all part of the sensor circuit. One sensor outputs analogue data, which is converted to digital data by the controller's ADC, and the other sensor outputs digital data, which is then processed to obtain temperature, humidity, and dew point temperature. An LCD display will show the measured parameters. A GSM/Wi-Fi/Bluetooth/ZigBee unit is connected to a mobile or laptop or desktop computer in the receiver area [7].

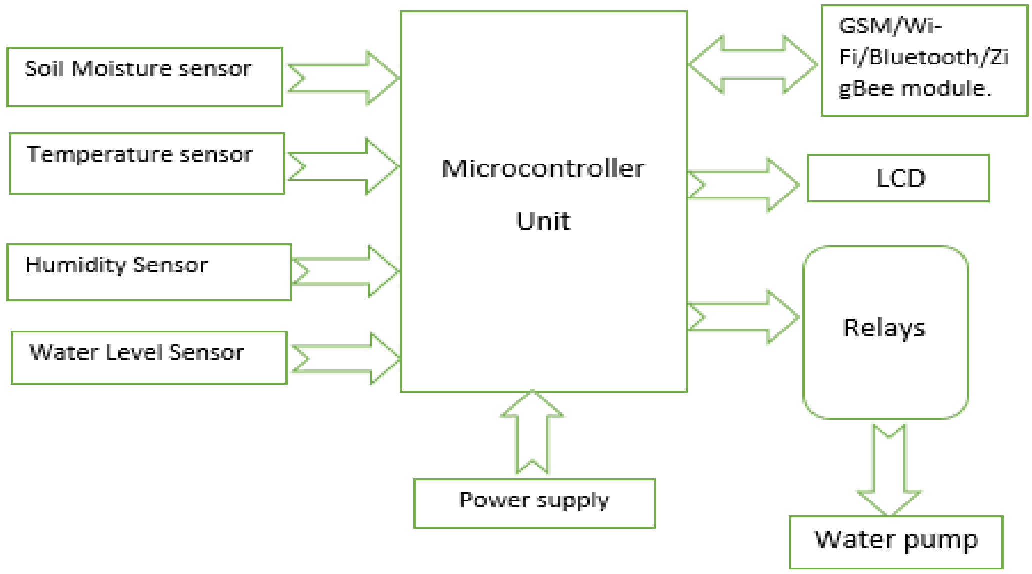

Fig 1: System block diagram

Temperature sensor, humidity sensor, soil moisture sensor, light sensor, and GSM/Wi-Fi/Bluetooth/ZigBee module are used in smart agriculture employing microcontroller-based GSM/Wi-Fi/Bluetooth/ZigBee technology. All of the sensors have been successfully connected to the microcontroller. Each sensor is linked to the microcontroller independently. GSM, Wi-Fi, Bluetooth, and ZigBee were all supported by the microprocessor. The processor also receives data from sensors on a regular basis in the form of AT commands [1]. This microcontroller sends all of the data collected by each sensor to GSM/Wi-Fi/Bluetooth/ZigBee and displays it on the LCD. The microcontroller sends all of the data acquired by the sensors to the GSM/Wi-Fi/Bluetooth/ZigBee, which is then utilized to deliver the message to the mobile phone. So we get an illness name and treatment for that disease on our phone [4].

III. ARCHITECTURE OF THE SYSTEM

3.1 The Microcontroller Module

The microcontroller is the system's beating heart. The Microcontroller receives input from analogue and digital sensors. The display unit is a microcontroller output. It receives analogue and digital signals equivalent to the quantity of the variable to be measured from sensors connected to it, and converts and processes them using pre-programmed instructions written in specific language (c, python, etc.) to ensure that the results obtained by all of these sensors are available in forms that are meaningful and useful for human analysis, interpretation, and validation [7].

3.1.1 Arduino UNO

The Arduino board has a variable number of pins. The pins are divided into output and input pins. The input pins take both digital and analogue data. There are 14 digital pins and 6 analogue pins on it. It requires 7 to 20 volts of electricity to operate. It also includes a USB port. The Arduino U was the first iteration of the Arduino series to be announced [8].

3.1.2 ArduinoMega 2560

The Arduino Mega 2560 is intended for the development of Arduino-based robots as well as research into 3D printing technologies. Technical Information: The Arduino Mega 2560 is based on the ATmega2560 microcontroller. It has 54 digital input/output pins, 16 analogue inputs, and 4 UARTs (Universal Asynchronous Receiver and Transmitter). Connects easily to a PC through a USB port [9], [10].

3.1.3 PIC24FJ64GB004

A 16-bit microcontroller with 44 pins using Nano Watt XLP technology that runs at 8 MHz with an inbuilt oscillator and works in the 2.0 to 3.6 V range. It contains up to 25 digital input/output ports, 13- and 10-bit analogue to digital converters (ADCs), two serial peripheral interface modules, two UARTs, two I2Cs, five 16-bit timers, 64 KB of programme memory, 8 KB of SRAM, and a hardware real-time clock/calendar (RTCC). Because of its low-power operating current of 175 A at 2.5 V at 8 MHz and 0.5 A for standby current in sleep mode, the microcontroller is ideally suited for this distant application [11].

3.1.4 PIC16F877A

It contains packages with 40 pins. A 10-bit A/D converter is included. The clock frequency of the microcontroller is 20 MHz. It contains five ports, starting with Port A and ending with Port E. It has three timers, two of which are 8 bit and one of which is 16 bit [4], [7].

3.1.5 LPC1768 (ARM PROCESSOR)

The LPC1768 has up to 512 kb of flash memory, 64 kb of data memory, Ethernet MAC, 4 UARTs, 8-channel general purpose DMA controller, 2 CAN channels, 2-input plus 2-output I2S-bus interface, USB Device/Host/OTG interface, 8-channel 12-bit ADC, 10-bit DAC, motor control PWM, Quadrature Encoder interface, 2 SSP controllers, SPI interface, 3 I2C-bus interfaces, 4 general purpose timers, 6-output general purpose PWM, ultra-low power Real-Time Clock (RTC) with separate battery supply, and up to 70 general purpose I/O pins. The LPC1768 is pin-compatible with the LPC236x ARM7-based microcontroller family, which has 100 pins [12].

3.2 GSM Module

The GSM (Global System for Mobile Communication) is a digital mobile phone network that is widely used throughout the world. It is the most widely used of the three digital wireless telephone technologies (TDMA, GSM, and CDMA), employing a variant of Time Division Multiple Access (TDMA). GSM digitizes and compresses data before sending it down a channel with two other user data streams, each with its own time slot. GSM uses the frequencies 900, 1800, and 1900 MHz [14].

3.2.1 GSM Sim 900A

The GSM/GPRS Modem-RS232 is equipped with a Dual Band GSM/GPRS engine- SIM900A, which operates at frequencies of 900/ 1800 MHz The modem has an RS232 interface that connects a PC as well as a microcontroller with an RS232 chip (MAX232). The baud rate can be set between 9600 and 115200 using the AT command. The GSM/GPRS Modem includes an internal TCP/IP stack that allows you to connect to the internet via GPRS. It is appropriate for SMS, Voice, and DATA transfer applications in M2M interface. You may connect a broad range unregulated power source to the on-board Regulated Power Supply. You may use this modem to make audio calls, send SMS, read SMS, answer incoming calls, and access the internet, among other things, by using basic AT instructions [4]. The GSM module operates at the following frequencies: 850 MHZ, 900 MHZ, 1800 MHZ, and 1900 MHZ. The modem employs 3V and 5V DC TTL interfacing hardware, allowing the user to connect directly with 5V microcontrollers. The modem may be connected to a microcontroller using USART [7].

3.3 Wi-Fi Module

The ESP8266 Wi-Fi Module is a SOC that includes a TCP/IP protocol stack, allowing any microcontroller to connect to a wireless network. The ESP8266 module is a low-cost module that supports APSD for VOIP and Bluetooth co-existence interfaces. 802.11b/g/n Wi-Fi Direct, 1MB Flash Memory, SDIO 1.1/2.0, SPI, UART, 1.0mW Standby Power Consumption [9].

3.4 Bluetooth Module

Bluetooth may be used to link the Central Monitoring Unit. On 3.3V, both the microcontroller and Bluetooth function. In AT mode, the Bluetooth module linked to the ARM controller is set as a BT-slave. Connecting Bluetooth to microcontrollers: Because both the microcontroller and Bluetooth operate at 3.3V, their pins may be linked directly without the use of a level shifter. The microcontroller's software communicates with the Bluetooth module via the UART serial communication mechanism. The Bluetooth module has an interior range of 50 to 70 meters and an outdoor range of roughly 100 meters [17].

3.5 ZIGBEE

ZigBee is primarily intended to replace existing non-standard technologies in a wide variety of applications. ZigBee modules are networked for communication in applications such as irrigation and fertilization, for example, drip irrigation utilized to monitor soil contents such as moisture. In addition, SMS is sent to the farmer to keep him up to date on field data, where GSM is necessary for long distances and a Bluetooth module can assist for lesser distances [3].

Parameter	Wi-Fi	Bluetooth	ZigBee
Standard	IEEE 802.11 a, b, g, n	802.15.1	802.15.4
Frequency	2.4 GHz	2.4 GHz	868/915 MHz, 2.4 GHz
Data rate	2–54 Mbps	1–24 Mbps	20–250 kbps
Transmission Range	20–100 m	8–10 m	10–20 m
Topology	Star	Star	Tree, star, mesh
Power Consumption	High	Medium	Low
Cost	Low	Low	Low

Table 1: Comparison of existing wireless module [18], [19].

3.6 Soil Moisture Sensor

The Soil Moisture Sensor detects the amount of moisture in the soil. It measures the amount of moisture or water content in the soil. Coefficients are used to do the computations in the soil moisture sensor. It calculates the amount of water in the soil. It measures the amount of water in the soil and receives and transmits analogue signals that are displayed digitally. It sends signals to microcontroller that contain information, data, or values about the state of the soil, which microcontroller then processes and displays [8].

For example, two wires are removed from the sensors that are embedded in the soil, and the soil moisture content is checked; if the soil is dry, the GSM sends the user an SMS that says “SOIL IS DRY.” After watering the field, the soil becomes moist, and GSM sends an SMS to the user saying "SOIL IS WET." In addition, the information will be shown on an LCD monitor [14].

Technical Specification: 3.3V to 5V; Analog Output; VCC external 3.3 V to 5V [9].

3.7 Water Level Sensor

It's possible that the water level rises to a critical level while the motor continues to operate. To avert such a disaster, a system for monitoring the water level should be in place. We employ a circuit in which two probes are placed within the tank; when the water in the tank comes into contact with one of the probes, the circuit is shorted, indicating that the tank is full. As a result, the motor will be shut off. When the water level falls below a certain level, the circuit becomes open, indicating that the water level is low, and the pump is activated [12].

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3.8 Humidity Sensor

A humidity sensor, commonly known as a hygrometer, detects and reports the relative humidity in the air on a regular basis [14]. The HDC1010 digital humidity sensor is employed, which delivers precise moisture level measurement in a low-power environment. It maintains great stability in high-humidity environments. The WLCSP (Wafer Level Chip Scale Package) streamlines the design of circuit boards. The HDC1010 is more resistant to dirt, dust, and other contaminants in the environment. For storing standardizing coefficients, the HDC1010 includes nonvolatile memory. I2C is supported by the HDC1010 [13].

3.9 Temperature Sensor

The temperature of the surrounding environment must be monitored not only for the crop's proper growth but also to prevent self-destruction. This technique allows the farmer to have complete information about his property on his phone. He can also learn a lot more information about his property [1].

LM35	DS18B20	TMP007
It is a temperature sensor that provides the microcontroller processor with values in degrees Celsius. We can do direct temperature detection or remote temperature control here. This temperature sensor IC operates within the nominal temperature range of -50 to +150 degrees Celsius. These are precision ICs with a linear output, meaning the voltage at the output is proportional to the temperature in Celsius. This IC will be connected to a microcontroller CPU through ADCI [1].	The DS18B20 temperature sensor measures temperatures from 9 to 12 bits in Celsius and features an alert function with non-volatile user-programmable higher and lower trigger points. The DS18B20 contains a 64-bit serial code that allows many DS18B20s to communicate over a single cable. Technical Specifications: One-Wire Interface; Measures temperature from -55°C to +125°C; Converts temperature to 12-bit digital word in 750ms [9].	It comprises of a math engine that compares the comparable change in voltage across the thermopile to the internal cold-junction reference (1°C (max) from 0°C to +60°C and 1.5°C (max) from –40°C to +125°C) digital control on the temperature sensor to determine the required field temperature. For storing standardizing coefficients, the TMP007 includes non-volatile memory. The TMP007 was created with mobility and low power consumption in mind (2.5V to 5.5V). The TMP007 is I2C and SM Bus compatible. TMP007 is 1.9 mm x 1.9 mm x 0.625 mm in dimension [13].

Table 2: Comparison of temperature sensors

3.10 UART (Universal Asynchronous Routing Technology)

There are four UARTs on each microcontroller. UART1 provides a full modem control handshake interface in addition to normal transmit and receive data lines. A fractional baud rate generator is included with the UARTs. Any crystal frequency above 2 MHZ can be used to obtain standard baud speeds like 115200 Bd. Infrared communication is supported through an IrDA mode on the UART. DMA is supported by all UARTs [1].

3.11 Relays

A relay is an electromagnetic device that connects two circuits magnetically while electrically isolating them. They're quite handy since they allow one circuit to switch another while they're still entirely distinct. They're frequently used to connect an electronic circuit (with a low voltage) to an electrical circuit (with a very high voltage). A relay, for example, may switch a 230V AC mains circuit using a 5V DC battery circuit [15]. In this system, relays are utilized to switch the pump set, DC motor, and solenoid valve [16].

3.12 Liquid Crystal Display (LCD)

LCDs are increasingly being replaced with LEDs (seven segment LEDs or other multi segment LEDs). These components are "specialized" for use with microcontrollers, which implies that conventional IC circuits cannot activate them. They're utilized to write various messages on a small LCD display [15].

IV. CONCLUSION

Wireless field monitoring saves time and money by allowing customers to view real-time changes in agricultural output. It is less costly and consumes less energy. Microcontrollers, GSM, Wi-Fi, Bluetooth, and ZigBee technologies, as well as IoT-based agriculture, have been proposed for live temperature, humidity, and soil moisture monitoring, among other things, to assist farmers in enhancing agricultural productivity and effectively managing food production. It may be improved further by integrating a few more capabilities such as intruder detection, illness detection that affects the quality of the product, crop recommendations based on expected environmental conditions, and soil fertility.

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