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ARTICLE

Internet of Things Based Smart Irrigation System Using ESP WROOM 32

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ABSTRACT

Farming has been the most prominent and fundamental activity for generations. As the population has been multiplying exponentially, the demand for agricultural yield is growing relentlessly. Such high demand in production through traditional farming methodologies often falls short in terms of efficiency due to the limitations of manual labour. In the era of digitization, smart agricultural solutions have been emerging through the windows of Internet of Things and Artificial Intelligence to improve resource management, optimize the process of farming and enhance the yield of crops, hence, ensuring sustainable growth of the increasing production. By implementing modern technologies in the field of farming we can enable telemetry through which farmers can remotely monitor and gather real time data on the desired parameters. It also gives accurate and precise measurements when compared to traditional measurement techniques. This research paper focuses on an IoT based approach for smart monitoring using ESP WROOM 32 microcontroller that helps farmers identify real-time parameters of temperature, moisture and humidity of their field. Real-time data on temperature, moisture, and humidity enables farmers to make informed decisions about irrigation and crop protection. Furthermore, the use of smart monitoring ensures accurate and precise measurements, surpassing the limitations of traditional techniques.

KEYWORDS

Smart monitoring; IoT; ESP WROOM 32; DHT11; soil moisture sensor; smart agriculture

1 Introduction

Kevin Ashton, the Father of IoT, stated that "The Internet of Things has the potential to change the world, just as the Internet did, maybe even more so". IoT plays a crucial role in connecting physical objects and enabling seamless data exchange and communication, leading to improved efficiency, productivity, and decision-making in various domains, including agriculture. In recent years, IoT has emerged as a game-changing technology with the potential to revolutionize industries, improve efficiency, and enhance the quality of life. The proliferation of internet connectivity, advancements in sensor technology, and the exponential growth of data have paved the way for IoT's widespread adoption [1]. IoT technologies in agriculture enable remote monitoring of environmental parameters such as soil moisture, temperature, humidity, and light intensity, providing real-time data for precise resource management and optimization of crop growth conditions. Based on the latest predictions the world population is expected to reach more than 9 billion and thus to serve this much of population by the time of 2050, the agriculture industry must expand all its capacity towards mega-scale production incorporating various technologies, for automating all its production tasks. Nevertheless, it is evident that it requires a boost of 70% by the time of 2050 to serve that much of the population. However, the latest studies have indicated that the crop yield has not progressed significantly in recent years. Consequently, there has been a direct impact on food prices which are continuing to grow rapidly since the agricultural supply is unable to keep up with its demand [2–5]. On the other hand, as of now, the worldwide supply system has been disrupted by the emergence of the COVID-19 global pandemic, resulting in food shortages and inflation. The urgent need for developing systems that facilitate the implementation of agricultural activities remotely has been realised during this pandemic. Thus, the future market development is projected to be driven by smart agriculture methods, where it has the potential to assist farmers by enabling remote farming to recuperate losses in a comparatively shorter time frame [6]. Various applications of IoT in the field of smart agriculture have been depicted in Fig. 1 below.

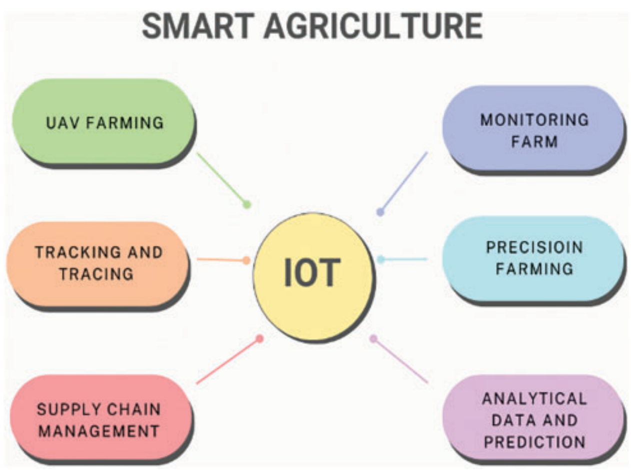


Figure 1: Applications of IoT

The idea of integrating IoT in the field of agriculture offers a plethora of benefits. A few of them are listed below:

- IoT enables automation and remote monitoring of agricultural practices.
- IoT provides real time updates of data on various parameters which allow farmers to take data driven decisions.
- IoT can boost the efficiency of farming activities by automating tasks such as pest control, irrigation, and fertilization.
- Sustainability and resource management are also possible with the help of IoT based smart farming.

2 Literature Survey

In recent years, several works have focused on IoT amplification for agriculture. In [7], authors presented the precision farming accounting temperature, humidity, sprinkler water flow and soil moisture. In [8], authors presented an irrigation system that implements soil sensors to get moisture level and object proximity. The proposed projects [9,10] illustrated the work's focus on precise irrigation. The outcome of the survey clarifies there are multiple sensors employed to monitor and track the irrigation level at the farm. Fig. 2 exemplifies the number of sensors that account for deciding the amount of irrigation level.

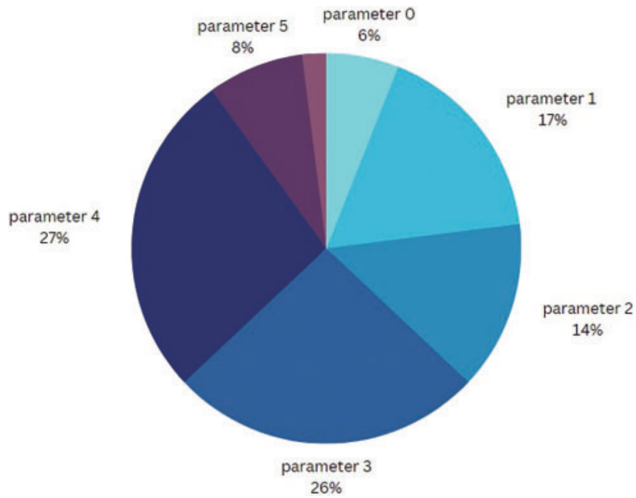


Figure 2: Number of irrigation parameters employed in papers [11]

In [11], an environment where the parameters are gathered, choice of parameters, and different sensors employed are presented in various research contributions. Though, several solutions prosed to have precise irrigation, we identified there are a few more challenges to be addressed.

- Each variety of crops demands a different irrigation amount (system to be crop independent).
- Seed to cultivation, different levels of irrigation to be carried out (system should account for the day of irrigation).
- Sustainable irrigation system.

3 Literature Review

A brief overview of existing work from various papers, which have been referred for implementation.

The survey by Ayaz et al. [12] highlighted the immense potential of wireless sensors and IoT in revolutionizing agriculture by offering real time data and monitoring. They also included the challenges expected to be faced when integrating this technology with traditional farming practices.

The research paper published by Arakere et al. [13] eliminated numerous problems faced in the process of irrigation in the world of agriculture. Some of the common challenges include overestimation or underestimation of the quantity of water to be supplied on the field, inaccuracy in the measurement of the moisture content in soil, the variation of various parameters of soil throughout the field, and many other limitations. These problems are overcome by a smart solution for irrigation systems which helps us digitize the monitoring and control over the irrigation system. It allows the farmer to acquire precise and accurate data of some parameters such as moisture content, temperature and humidity levels across the field to optimize the process of irrigation. This upgrades the management of resources and efficiency in the consumption of time and energy.

Another notable work by Amin et al. [14] proposed an IoT based smart model which can be used for onsite and as well as offsite monitoring various parameters by means of Arduino, temperature and humidity sensors, soil moisture sensor, barometric pressure sensor, flame sensor, smoke sensor, and DC motor to monitor and control environmental parameters in agricultural field.

In a research paper published by Dahane et al. [15], the development of a design and experimentation of a smart farming system based on an intelligent platform has been exhibited which allows precision predictions using artificial intelligence techniques. They followed a path which included data collection, data cleaning and storage and finally predictive processing using AI. The implemented smart farming system was found to be feasible and cost effective for optimizing water resources for agriculture of precision. The main objective of this paper was to design a new EDGE-Fog-IoT-Cloud based architecture dedicated to the smart farming.

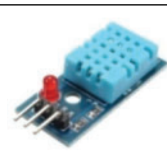
Rahman et al. [16] found that surface irrigation is one of the common irrigation techniques where we see a lot of wastage of water. To overcome this problem, they have developed a smart solution which involves building an IoT environment to reduce human interference in farming. Sensors play a crucial role in the field of IoT. These sensors provide analog signals which could be further converted into digital output. Here, at first, the information is extracted from the data server, thereafter the IoT network is linked. Rain sensor is also placed so that if there is no possibility of rain the process can further move to the sprinkler controller. Further humidity sensor, temperature sensor and moisture sensor are used for other vital information. ESP8266 microcontroller is used as a processing unit. TCP/IP (Transmission Control Protocol/Internet Protocol) protocol is used for communication using API (Application Programming Interface), which helps in checking authenticity of the device before setting up communication. These processes allow the user to track and control the moisture level and water consumption.

Urmeneta et al. [17] have developed a design to monitor the soil pH and moisture content which can provide precise and reliable measurements for the users. The design uses an Arduino microcontroller to do all the hardware and software integration. A mobile application has also been developed through which the farmer can remotely monitor and control the parameters.

4 Development Setup for the Experiment

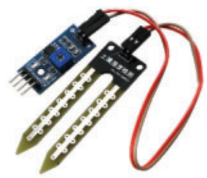
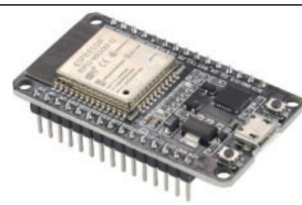
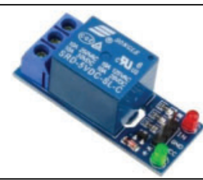
This portion provides a brief insight of the hardware components employed in the proposed smart irrigation system based on the Internet of Things in Table 1.

Table 1: Hardware specifications

S. No.	Name of the components	Image	Specifications
1.	DHT11 (Temperature and humidity)		Power supply: (3.3–5.5) V Humidity scale: (20–90) % Temperature scale: (0–50)°C Precision: ± 2 Resolution: 1 Compatibility

(Continued)

Table 1 (continued)

S. No.	Name of the components	Image	Specifications
2.	Soil moisture sensor		Power supply: (3.3–5.5) V Humidity scale: (20–90) % Temperature scale: (0–50)°C Precision: ± 2 Resolution: 1 Compatibility
3.	ESP VROOM 32 microcontroller		Crystal oscillator: 40-MHz Integrated SPI flash: 4 MB Operating voltage/power supply 3.0∼3.6 V
4.	Relay		Power supply: 5 V Maximum load: 10 amps at 250 volts AC
5.	Motor pump		Power supply: 3–6 V Operating current: 130∼220 mA Flow rate: 80∼120 L/H Maximum lift: 40∼110 mm

5 Methodology

The proposed design for smart irrigation monitoring and control system, as shown in Fig. 3, allows a farmer to remotely control the irrigation system using ThingSpeak.

The smart irrigation system consists of two sensors, DHT11 and Soil Moisture Sensor which acquire data from the agricultural field, and hence, form the physical layer of the model of this system. DHT11 sensor measures the temperature and humidity of the field which is then uploaded on the cloud of ThingSpeak and can be accessed through its website. Soil Moisture sensor detects the moisture level present in the soil and the control is modulated accordingly.

The network layer of the model is formed by enabling internet connectivity for the system. This is achieved by a Wi-Fi module which is embedded into the ESP WROOM 32. The system can now be connected to the internet and communication can take place among the user's computer, cloud, and the device.

The data that has been gathered needs to be stored and processed so that the information can be utilized. The responsibility of storing and processing the data is taken by an IoT analytics platform service, ThingSpeak. This platform provides an interface for the user to interact with the gathered data. It also provides a cloud storage for maintaining the recorded data. This forms the middleware layer of the model.

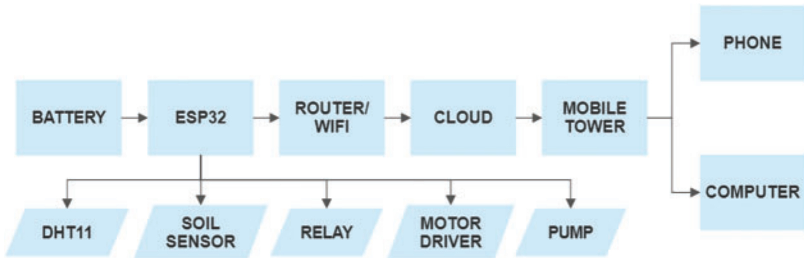


Figure 3: Block diagram

ThingSpeak also helps to manage the controlling part of the system and form the application layer of the model. It has in-built features that send an alert via email to the user as the water pump turns on and off depending on various parameters like humidity, temperature, and pressure conditions in the agricultural field.

The hardware setup of the device is surprisingly simple and cost effective. First, the ESP WROOM 32 is connected to a computer via a USB (micro-USB) cable to feed the desired code into the microcontroller through software applications like Arduino IDE (Integrated Development Environment). Once the code is fed to the microcontroller, it needs only a power source to function. For demonstration, the power source used in the experiment is a laptop. Further, the microcontroller is placed on a breadboard and is connected to the other peripherals using jumper wires. The soil moisture sensor and DHT11 sensor have their negative terminals connected to the GND pin, the DATA pin of the soil moisture sensor is connected to an analog GPIO (General Purpose Input Output) pin and the VCC pin of the sensors is connected to the 5 V power supply from the microcontroller. Next, a relay and a DC motor, demonstrating the irrigation pump, are connected to the setup. The negative terminal of the battery is connected to one terminal of the motor and the remaining terminal of the motor is connected to the common pin of the relay and the ON pin of relay is connected to the positive terminal of the battery. The IN pin of the relay is connected to a digital GPIO pin of the microcontroller, the GND ping of the relay is connected to the GND pin of the microcontroller, the VCC pin of the relay is connected to the 5 V power supply from the microcontroller. Thus, the hardware setup of the device is complete.

6 Result and Discussion

Using the proposed setup, the user can monitor all the parameters of the field, i.e., Humidity, Temperature, and Soil moisture via ThingSpeak. The user might as well control the irrigation system precisely which would prevent overwatering or underwatering the field. The system also allows the user to automate this process by specifying the desired minimum and maximum limits for the level of moisture content of the soil to be irrigated. The hardware model of the setup consists of the sensors (DHT11 and soil moisture sensor), a relay (switch), a motor (actuator), a battery (power source) and an ESP WROOM 32 microcontroller (processing unit). The sensors are responsible for measuring important parameters from the corresponding measurand. These are the only components of the system which require physical contact with the field. This data is then transferred to the microcontroller and is processed such that it can be uploaded on the cloud via an in-built Wi-Fi module. The microcontroller also controls the actuator, i.e., a motor pump, depending on the moisture content. A relay is used for the purpose of turning the motor on/off depending on the output from the microcontroller (HIGH/LOW). The prototype of the hardware setup of the proposed system where multiple components are depicted such as sensors, microcontroller, and motor controller to demonstrate the actual working of the system is shown in Fig. 4.

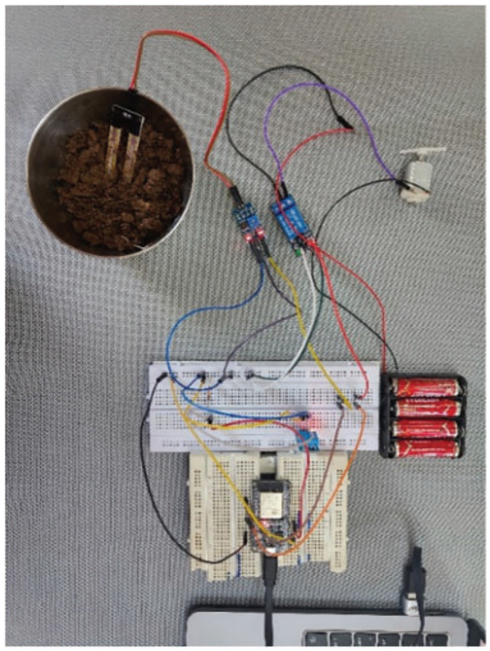


Figure 4: Hardware setup

The uploaded data is stored in the cloud storage for the purpose of statistical analysis and maintaining a record. The cloud service of ThingSpeak is being used in this system to display all the recorded parameters and status of the motor. Updates of the data are reflected on the cloud every 15 s and are displayed on the user interface of ThingSpeak. The graphical representation of the gathered data through Thingspeak's user interface is shown in Fig. 5.

The Smart Irrigation System using IoT has successfully been implemented in the form of an experimental prototype and is ready to be scaled for a practical application with few upgrades. However, the implementation of the proposed design can also be executed by means of various other technologies.

Let us consider the research paper published by Karpagam et al. [18], which demonstrates the implementation of a similar model based on Arduino UNO microcontroller. The wireless communication system of the model uses a GSM (Global System for Mobile Communication) module for internet connectivity. When compared to an ESP WROOM 32 microcontroller, Arduino UNO has one major drawback, that is, Arduino UNO does not have an in-built Wi-Fi module, GSM module or a ZigBee chip to enable wireless internet connectivity for the system. The setup contains a GSM module which enables long distance wireless network connectivity; however, it brings a set of disadvantages alongside. When compared to a Wi-Fi module, a GSM module demands more power to operate and is slower. Also, the Wi-Fi module is considerably cheaper than the GSM module.

Another closely resembling system has been proposed in a research paper published by Rajput et al. [19]. The major difference is at the application layer of the of the model since they have 'Blynk' application instead of ThingSpeak. In contrast to ThingSpeak, which is a web application, Blynk is an Android/iOS application. Both these applications ultimately achieve the same purpose, that is, providing a cloud platform for the storage of the gathered data and providing an interface to interact with the system by allowing the user to monitor and control the data online remotely.

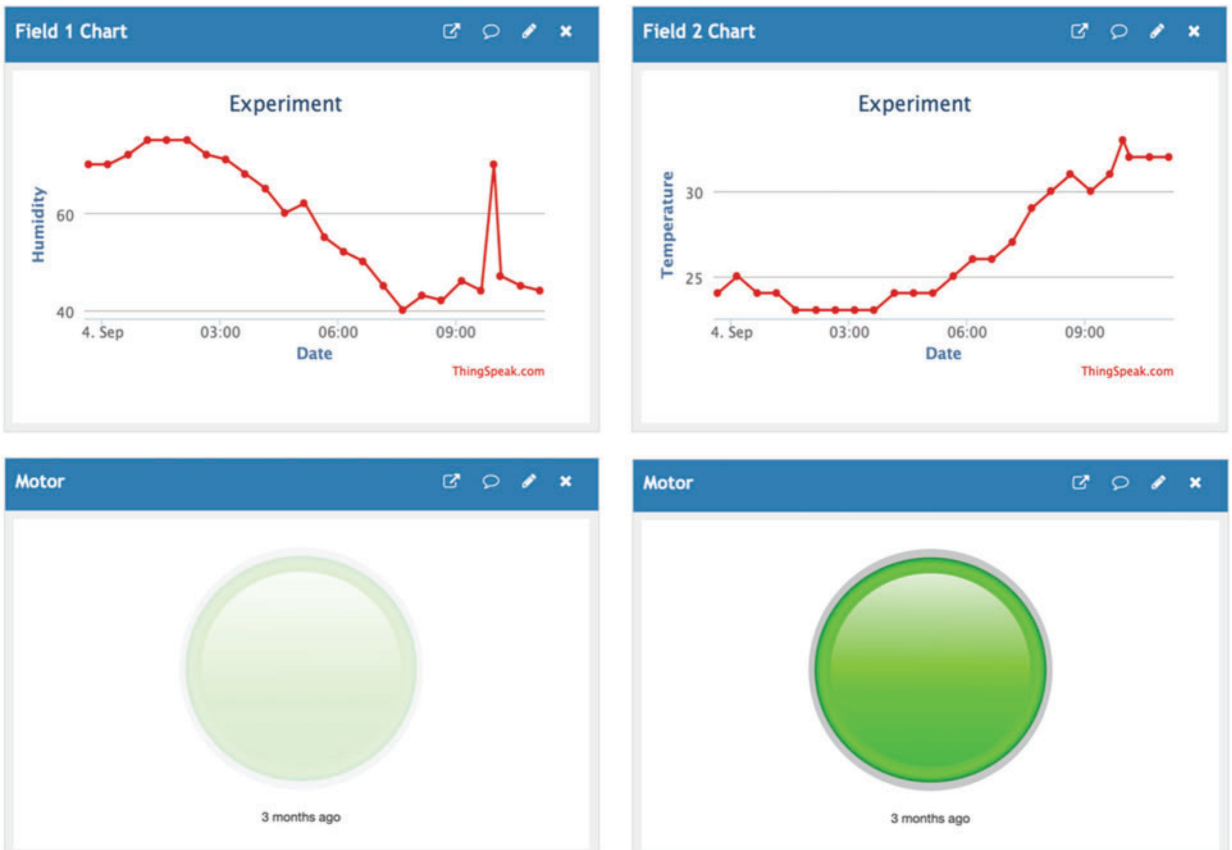


Figure 5: Thingspeak's user-interface

The smart agricultural system utilizes cutting-edge technology to provide farmers with precise and accurate measurements crucial for optimizing their farming practices. With the IoT-based approach employing an ESP WROOM 32 microcontroller, real-time data is continuously gathered from the field. For instance, temperature fluctuations are tracked with an accuracy of up to 0.1 degrees Celsius, enabling precise climate control. Moisture levels are monitored with a granularity of 1%, allowing for highly accurate irrigation scheduling. Humidity, vital for crop health, is recorded with a precision of 2%, ensuring the optimal conditions for plant growth. These numerical measurements, far superior to traditional techniques, empower farmers to make data-driven decisions that lead to increased crop yields and sustainable agricultural growth.

The ESP32 offers advantages over traditional Arduino boards, featuring a dual-core processor with speeds up to 240 MHz, more memory (RAM (Random Access Memory) and flash), built-in Wi-Fi and Bluetooth, GPIO pin count larger, multiple analog inputs, and operates at 3.3 V. These features make the ESP32 especially suitable for applications that require high processing power, wireless connectivity, and expanded I/O capabilities.

Analysis of the provided graphs reveals a notable decrease in relative humidity by approximately 30% over a 9-h period. This reduction is correlated with the diurnal temperature variation, where the temperature increases from 24 degrees Celsius at sunrise to 33 degrees Celsius. This rise in temperature contributes to enhanced evaporation rates, leading to a reduction in ground moisture content. Furthermore, examination of moisture level data exhibits an automated irrigation system in operation. When the moisture level decreases to a predetermined threshold, specifically 30%, an automatic water pump is initiated. This system efficiently restores soil moisture to 60%, at which point the pump ceases operation. This process repeats cyclically, ensuring that soil moisture remains within the desired range, indicating a controlled and responsive irrigation system.

7 Conclusion

This research paper centres around the implementation of an IoT-driven strategy for intelligent monitoring in agriculture, utilizing the ESP WROOM 32 microcontroller. The incorporation of IoT technology in agriculture brings about numerous advantages, including automated and remote monitoring of farming practices, real-time data updates for informed decision-making, increased efficiency through task automation, and sustainable resource management. The paper also delves into relevant studies in the field, emphasizing the potential of wireless sensors and IoT in revolutionizing agriculture and overcoming challenges related to irrigation, environmental parameter monitoring, and precision farming. The proposed IoT-based smart monitoring system enables real-time tracking of temperature, moisture, and humidity parameters, empowering farmers to optimize their farming processes and enhance crop yields. By harnessing the potential of IoT and AI technologies, this research contributes to the sustainable expansion of agricultural production and offers a pathway towards effective resource management in response to escalating demands.

8 Future Scope

The implementation of this design leads us to infer that there is a large room for improvising and innovating the concept to bring the fullest out of its potential. We could be witnessing smart gadgets in the agricultural field that will exhibit the era of automation practically soon enough. Apps could be built to ease access to the data, machine learning and data mining techniques could be implemented for strategic improvements and predictive analysis based on the recorded data, nourishing the soil by automating the process for fertilizing the field could be implemented by means of sensors which indicate nutrient and/or pH levels of the soil, advanced sensors could be installed like pest infestation indicators, etc. Altogether, there is a huge amount of potential hidden in this concept.

Some smart irrigation systems use data analytics to identify patterns and trends in water usage. Farmers can use this information to make informed decisions about irrigation practices and resource allocation. Smart irrigation technologies often include features such as drip irrigation, which is more water-efficient than traditional sprinkler systems. Drip irrigation delivers water directly to the root zone, minimizing water loss due to evaporation.

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References

[1] Md. A. I. Fahim and S. A. Tumpa, "The importance of IoT: Transforming industries, enhancing lives, and shaping the future," 2023. https://doi.org/10.13140/RG.2.2.14681.08800
[2] W. S. Kim, W. S. Lee and Y. J. Kim, "A review of the applications of the Internet of Things (IoT) for agricultural automation," *Journal of Biosystems Engineering*, vol. 45, pp. 385–400, 2020.
[3] R. K. Kodali and A. Sahu, "An IoT based soil moisture monitoring on Losant platform," in *2016 2nd Int. Conf. on Contemporary Computing and Informatics (IC3I)*, Greater Noida, India, pp. 764–768, 2016.
[4] J. Kim, S. Kim, C. Ju and H. I. Son, "Unmanned aerial vehicles in agriculture: A review of perspective of platform, control, and applications," *IEEE Access*, vol. 7, pp. 105100–105115, 2019.
[5] R. S. Chowhan and P. Dayya, "Sustainable smart farming for masses using modern ways of Internet of Things (IoT) into agriculture," in *Smart Devices, Applications, and Protocols for the IoT*. Hershey, PA, USA: IGI Global, pp. 189–219, 2019.
[6] N. N. Thilakarathne, H. Yassin, M. S. Abu Bakar and P. E. Abas, "Internet of Things in smart agriculture: Challenges, opportunities and future directions," *2021 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE)*, pp. 1–9, 2021. https://doi.org/10.1109/CSDE53843.2021.9718402
[7] K. Kansara, V. Zaveri, S. Shah, S. Delwadkar and K. Jani, "Sensor based automated irrigation system with IOT: A technical review," in *2021 IEEE Asia-Pacific Conf. on Computer Science and Data Engineering (CSDE)*, Brisbane, Australia, pp. 1–9, 2015. https://doi.org/10.13140/RG.2.1.3342.3129
[8] P. Munoth, R. Goyal, K. Tiwari and P. D. Scholar, "Sensor based irrigation system: A review," *International Journal of Engineering Research & Technology*, vol. 4, pp. 86–90, 2016.
[9] S. Jain and K. S. Vani, "A survey of the automated irrigation systems and the proposal to make the irrigation system intelligent," *International Journal of Computer Sciences and Engineering*, vol. 6, no. 1, pp. 357–360, 2018.
[10] L. García, L. Parra, J. M. Jimenez, J. Lloret and P. Lorenz, "IoT-based smart irrigation systems: An overview on the recent trends on sensors and IoT systems for irrigation in precision agriculture," *Sensors*, vol. 20, no. 4, pp. 1042, 2020.
[11] R. Vijay, Y. V. Priya, P. C. Reddy, S. Monisha and V. Ramasamy, "A IoT based smart auto irrigation system," in *2023 Int. Conf. on Computer Communication and Informatics (ICCCI)*, Coimbatore, India, pp. 1–4, 2023. https://doi.org/10.1109/ICCCI56745.2023.10128325
[12] M. Ayaz, M. Ammad-Uddin, Z. Sharif, A. Mansour and El. M. Aggoune, "Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk," *IEEE Access*, pp. 129551–129583, 2019. https://doi.org/10.1109/ACCESS.2019.2932609
[13] M. G. Arakere, S. Avik and B. T. Tejomurthula, "Smart irrigation system using IoT," 2019. https://doi.org/10.13140/RG.2.2.36394.77764

[14] M. S. Amin, S. T. H. Rizvi, U. Iftikhar, S. Malik and Z. B. Faheem, "IoT based monitoring and control in smart farming," in *2021 Mohammad Ali Jinnah University Int. Conf. on Computing (MAJICC)*, Karachi, Pakistan, pp. 1–6, 2021. https://doi.org/10.1109/MAJICC53071.2021.9526247

[15] A. Dahane, R. Benameur, B. Kechar and A. Benyamina, "An IoT based smart farming system using machine learning," in *2020 Int. Symp. on Networks, Computers and Communications (ISNCC)*, Montreal, QC, Canada, pp. 1–6, 2020. https://doi.org/10.1109/ISNCC49221.2020.9297341

[16] M. T. Rahman, Y. Li, S. Mahmud and M. A. Rahman, "IoT based smart farming system to reduce manpower, wastage of time & natural resources in both traditional & urban mega farming," in *2021 4th Int. Conf. on Advanced Electronic Materials, Computers and Software Engineering (AEMCSE)*, Changsha, China, pp. 1180–1184, 2021. https://doi.org/10.1109/AEMCSE51986.2021.00241

[17] J. A. T. Urmeneta and J. R. N. de los Santos, "PlantOne: An arduino-based pH and moisture based soil plant identifier," in *2020 IEEE 12th Int. Conf. on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, Manila, Philippines, pp. 1–5, 2020. https://doi.org/10.1109/HNICEM51456.2020.9400019

[18] J. Karpagam, I. I. Merlin, P. Bavithra and J. Kousalya, "Smart irrigation system using IoT," in *2020 6th Int. Conf. on Advanced Computing and Communication Systems (ICACCS)*, Coimbatore, India, pp. 1292–1295, 2020. https://doi.org/10.1109/ICACCS48705.2020.9074201

[19] A. Rajput, S. Chaudhary, L. Varshney and D. Singh, "IOT based smart agriculture monitoring using node MCU AND BLYNK App," in *2022 Int. Conf. on Machine Learning, Big Data, Cloud and Parallel Computing (COM-IT-CON)*, Faridabad, India, pp. 448–451, 2022. https://doi.org/10.1109/COM-IT-CON54601.2022.9850847