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IoT-based real-time monitoring and control system for tomato cultivation

Hari Mohan Rai[a,b,*], Kaustubh Kumar Shukla[b], Yashika Goya[b], Saule Amanzholova[a], Askarbekova Nessibely[a]

[a]*Department of Cyber Security, International IT University, Almaty, Kazakhstan*
[b]*Department of Electronics and Communication, Dronacharya Group of Institutions, Greater Noida, India*

Abstract

IoT techniques have transformative potential across domains, particularly in precision agriculture, where they enable farmers to optimize crop production while minimizing environmental impact. This paper presents an IoT-based real-time monitoring and control system for hydroponic tomato cultivation. The system integrates various hardware components, including sensors for monitoring temperature, humidity, pH levels, and gas concentrations. Arduino microcontrollers collect and process sensor data, enabling automated control of water, nutrient supply, and ventilation. Wi-Fi and GSM modules facilitate remote monitoring and data transmission, empowering farmers to monitor and control their tomato crops remotely. The system has been successfully tested for tomato cultivation, demonstrating promising results. Although tailored for tomatoes, its design principles can be adapted for other crops. Moreover, it shows significant water and nutrient efficiency, highlighting its economic feasibility.

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Keywords: Internet of Things (IoT); Real Time Crop Monitoring; Tomato cultivation; Hydroponics; Arduino; Automatic farming.

1. Introduction

For years, media outlets have provided evidence of the struggles endured by farmers, shedding light on their difficulties in assessing soil quality and contending with the uncertainties of crop production. Farmers face concerns about adverse weather conditions, fluctuating temperatures, water levels, and other factors that can profoundly impact their livelihoods. Fig. 1 presents a sobering picture of the distressing number of farmer suicides that occurred in various states of India during the financial year 2023 [1]. Maharashtra reported the highest number of farmer suicides, totaling a staggering 2,708 cases. Following closely behind is Karnataka, where 1,323 farmers tragically took their own lives. Andhra Pradesh recorded 369 farmer suicides, while Telangana reported 178 cases. In Punjab, 157 farmers

* Corresponding author. Mob.: +7-705-192-2375.
E-mail address: r.hari@iitu.edu.kz

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succumbed to suicide, and Tamil Nadu documented 122 such incidents. These statistics underscore the severity of the issue and highlight the immense challenges faced by farmers across different regions of the country [2].

In the contemporary era, the fusion of Artificial Intelligence (AI) and IoT technologies has sparked a revolution in the agricultural sector, notably transforming crop monitoring and productivity forecasting [3]. This convergence of AI and IoT has empowered farmers with advanced tools and techniques to optimize crop yields, mitigate risks, and make informed decisions throughout the agricultural cycle. In the intricate tapestry of modern agriculture, the fusion of IoT technologies, from sensors to aerial drones, paints a vivid portrait of data-driven cultivation. Moreover, at the forefront of modern agriculture lies the synergy between AI and IoT technologies, fostering precision farming practices that harmonize inputs with crop and soil specifics [3]. This study utilizes IoT to monitor and control tomato

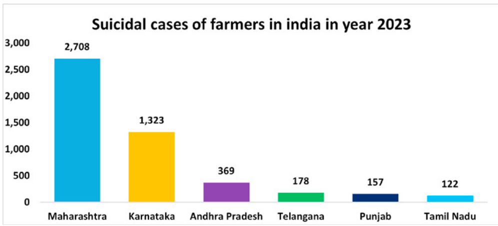


Fig. 1. State-wise distribution of farmer suicides in India for the Year 2023 [1]

crop growth in real-time. Using Arduino controller and various sensors, it automates environmental parameters such as pH, humidity, and temperature. Threshold-based controls manage water and nutrient pumps, fans, and ventilation. Data transmission via Wi-Fi or GSM allows remote monitoring.

2. Literature Survey

In recent years, researchers have conducted studies to boost crop productivity and monitor agricultural crops using AI, IoT, and hardware-based methods.

In [4, 5, 6], researchers have provided valuable insights into the utilization of IoT applications in agriculture automation. This study sheds light on the incorporation of IoT methodologies in agriculture systems, with the aim of facilitating smart agriculture. In [7, 8], researchers have extensively investigated the efforts of AI in agriculture. These studies provide comprehensive information on the various cases of AI use in agricultural practices, which includes crop monitoring, yield prediction, disease detection, and precision farming. In [9, 10], authors explore the use of ML and AI techniques in precision agriculture. They explore the utilization of predictive models and AI algorithms for tasks such as crop yield estimation, disease diagnosis, and pest management.

In [11, 12], authors have presented works on the application of DL in agriculture. Delving into the intricate realms of agricultural innovation, this study presents a panoramic exposition of deep learning methodologies. The authors delve into the utilization of deep learning models for tasks such as crop classification, weed detection, and yield prediction. In [13, 14], authors explore the Challenges and Opportunities of AI in Agriculture. The articles delve into the potential of AI technologies in addressing crucial challenges encountered by the agricultural sector, such as climate change, resource scarcity, and food security. Authors in [15, 16], discuss methodologies for real-time monitoring of crop health parameters including leaf color, texture, and disease symptoms using IoT sensors.

Research gaps persist in agricultural IoT and AI, including limited integration for crop health monitoring, a lack of tailored AI models, adoption barriers like data privacy concerns, and the necessity for interdisciplinary efforts.

3. Materials and Methods

In this section, we outline our methodology for implementing an IoT-based real-time monitoring and control system to improve tomato crop productivity. Fig. 2 shows the workflow of our approach, which begins with the integration of various hardware components. These include power supply modules for AC, DC (Battery) and solar power sources, as well as sensors for humidity, light, pH, water level, and temperature. For software implementation, we used a

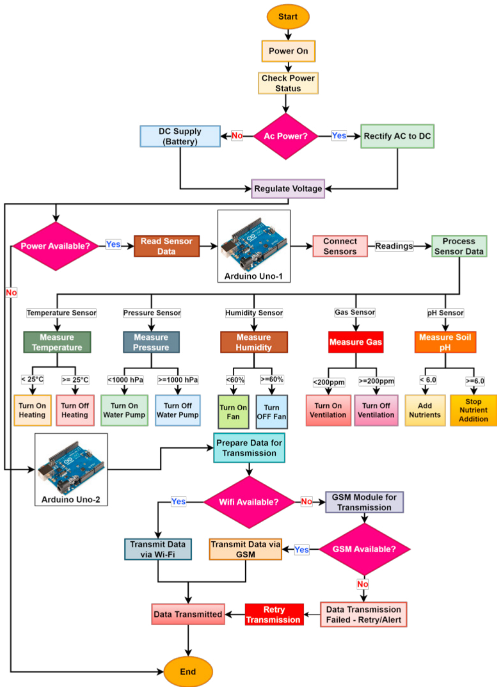


Fig. 2. Flowchart of the proposed IoT-based methodology for Real-time monitoring and control of tomato crop cultivation

multifaceted approach. The data collected by the sensors are processed within the Arduino board to extract relevant features. Upon system activation, sensors capture environmental metrics such as temperature, humidity, and light intensity. The Arduino microcontroller manages sensor readings and controls hardware components based on preset threshold values along with data transmission for remote monitoring. The hardware components used in the project are shown in Fig.3.

3.1. Power Supply and Temperature Sensor

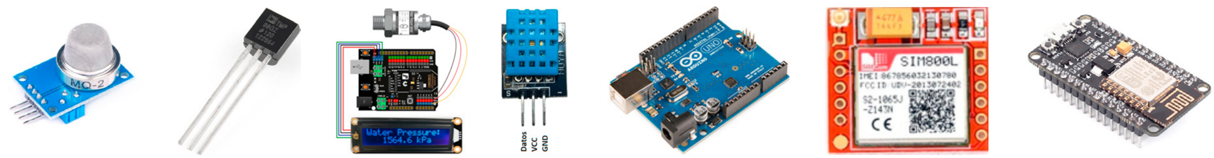
In our implementation, we utilize two types of power sources: AC and DC (battery), based on availability and operational needs. When the battery is unavailable, the system switches to AC power. Conversely, when AC power is unavailable, the system operates on DC power from the battery. Power regulators are integrated into the system design to ensure consistent and suitable power levels for the devices, enhancing overall reliability. Temperature sensors act as sophisticated transducers, adept at converting the intricate nuances of temperature fluctuations into precise electrical signals. We have used a TMP36 temperature sensor, which boasts a voltage operating range ranging from 3.3V to 5V [17].

3.2. Arduino

Arduino, renowned for its versatility, produces single-board microcontrollers and kits for the development of digital devices [18]. In our system, Arduino modules serve as central components. Sensors like light, pH, water level, temperature, and humidity are directly interfaced with Arduino boards. These boards not only acquire sensor data, but also supply power to them. With the ability to deliver both 3.3-volt and 5-volt DC power.

3.3. Pressure Sensor and Humidity Sensor

The Analog Water Pressure Sensor (SEN0257) [19] plays a critical role in our system, serving to monitor and regulate water pressure levels essential for controlling the motor pump used in irrigation processes. Featuring a three-pin interface and compatibility with Arduino Uno and other Arduino board variants, this sensor seamlessly integrates



(a) (b) (c) (d) (e) (f) (g)

Fig. 3. Hardware components for monitoring environmental conditions(a) Gas Sensor (MQ2), (b) Temperature Sensor (TMP36), (c) Water pressure sensor with Arduino and LCD [20], (d) Humidity sensor (DHT11), (e) Arduino, (f) GSM Module (SIM800L), and (g) WiFi Module (ESP8266).

into our setup. The Humidity Sensor serves as a pivotal component in our system, tasked with monitoring the real-time humidity levels within the enclosed environment designated for tomato cropping. Although capable of detecting both temperature and humidity, we have specifically employed DHT11 [21] Humidity Sensor to focus on humidity monitoring.

3.4. Gas and pH Sensor

In our setup for real-time environmental monitoring, we've integrated the MQ2 Gas Sensor [22]to accurately measure and monitor gas levels within the controlled room environment. This versatile sensor has the ability to detect a wide range of gases, including smoke, CO2, LPG, H2, and methane, which enhances its utility for our application. In our setup for precise water and nutrient management, we have incorporated the E-201C pH Sensor Kit to accurately measure the pH level of the water and nutrient solutions. Commonly referred to as a pH meter, this sensor kit is highly compatible with various versions of Arduino controllers, ensuring seamless integration into our project.

3.5. WiFi and GSM Module

To facilitate remote monitoring and data transmission of the sensor readings, we've integrated both WiFi (ESP8266) and GSM (SIM800L) modules into our setup. The serves as a reliable means of transmitting data over a wireless network. However, in cases where the WiFi connection may be unreliable due to internet issues, we've also incorporated the SIM800L GSM module as an alternative communication method. .

3.6. Ubidots platform

We have integrated the Ubidots platform into our system for real-time monitoring of sensor readings. Ubidots epitomizes a cloud-based IoT platform meticulously crafted to seamlessly gather, dissect, and depict sensor data in the ethereal realm of real-time. Its arsenal encompasses a rich array of tools, fostering a holistic environment for meticulous data surveillance and scrutiny, storage, visualization, and analysis, empowering users to create custom IoT applications and dashboards with ease, even without advanced programming skills.

4. Result and Experimentation

We have established a laboratory environment within a confined space of 12 feet by 15 feet on the first floor, dedicated to the cultivation of tomato crops. Our setup adopts a hydroponic-based approach for growing tomatoes, relying solely on water and nutrients to nurture the crops. The project environment, specifically tailored for the cultivation of tomato crops, is depicted in Fig. 4 ((a) and (b)).

In stage one, we use hydroponic seed germination with a specialized grow tray for tomato seeds. After 3 to 7 days, sprouts are ready for transplantation. In stage two, a hydroponic structure with four pipes supports plant growth. Two tanks, one with water and one with nutrient solution, are regulated by DC motors for precise nutrient distribution. In stage three, we achieved real-time monitoring and control by integrating hardware components. This included two Arduino Uno boards and various sensors like pH, water level, temperature, humidity, and gas sensors. We ensured continuous operation with AC and DC power supply options. The AC supply was converted to DC and regulated to 12 volts and 5 volts, powering pumps and Arduino boards respectively. Sensor data was processed by one Arduino

(a) (b) (c)

Fig. 4. Visualization of the project environment: (a) Hardware setup of hydroponic system, (b)Tomato plants cultivation, and (c) Sensors reading using Ubidots platform.

programmed in C++. Real-time monitoring was enabled through the Ubidots platform. We used a DC fan for humidity regulation and an exhaust fan for ventilation. Motor and fan control were based on predefined threshold values derived from sensor data.

Table 1 lists sensor types and their thresholds for an automated environmental control system. For example, the temperature sensor triggers heating below 25°C and stops it above. The pressure sensor activates the water pump below 1000 hPa. The gas sensor controls ventilation above 200 ppm. The humidity sensor activates the fan above 60% humidity. The pH sensor regulates nutrient levels, activating the nutrient pump below pH 6.0. Inputs from references and consultations ensured optimal tomato growing conditions.

Table 1. Types of Sensors, Threshold Values, and Operations

Types of Sensors	Threshold Value	Operation
Temperature Sensor	Below 25°C	Turn On Heating
	Above or Equal to 25°C	Turn Off Heating
Pressure Sensor	Below 1000 hPa	Turn On Water Pump
	Above or Equal to 1000 hPa	Turn Off Water Pump
Gas Sensor	Below 200 ppm	Turn On Ventilation
	Above or Equal to 200 ppm	Turn Off Ventilation
Humidity Sensor	Below 60%	Turn On Fan
	Above or Equal to 60%	Turn Off Fan
pH Sensor	Below 6.0	Add Nutrients/Turn on Nutrients Pump
	Above or Equal to 6.0	Turn off Nutrients Pump

Sensor readings for real-time monitoring on the Ubidots platform are shown in Fig. 4 (c). Monitored parameters include temperature, altitude, pressure, gas, humidity, and dew point. pH level and water pressure are displayed on the LCD screen as part of our monitoring setup. Hydroponics simplifies monitoring and control due to its closed environment. Integrating IoT sensors and automation provides farmers with real-time data and precise control over nutrients, water, and lighting, promoting sustainable and high-yielding crop production. In the final stage, we integrated the ESP8266 Wi-Fi module and the SIM800L GSM module to transmit sensor data. This allowed remote monitoring and real-time updates from locations such as our homes. Although we couldn't compare all parameters in our experiments, we observed excellent water utilization. Growing 1 kg of tomatoes required only 15-20 liters of water, compared to 50-60 liters for soil-based methods. Our project automates tomato crop monitoring and control with IoT devices.

5. Conclusion

Our research showcases a successful IoT-based system for real-time monitoring and control of tomato crop cultivation. Through hardware integration of sensors, Arduino microcontrollers, and communication modules, we automate critical environmental parameter management for optimal crop growth. Continuous monitoring of temperature, humidity, pH levels, and gas concentrations ensures ideal growing conditions for tomato plants. Utilizing the Ubidots platform enables remote sensor data monitoring, offering valuable insights into crop health and environmental conditions. Integration of Wi-Fi and GSM modules allows seamless data transmission and monitoring, enhancing accessibility for hydroponic farmers. Our work contributes to precision agriculture, optimizing tomato crop productivity and management with IoT technology. Significant improvements in water and nutrient efficiency highlight its economic feasibility.

Future work will involve using ML and DL for predictive crop yield insights from sensor data. Expanding the system's application to various crops and conducting a cost analysis for economic feasibility are also planned.

References

[1] Sandhya Keelery, Number of farmer suicides in India FY 2023, by state, Statista (2024). https://www.statista.com/statistics/1455499/india-number-of-farmer-suicides-by-state/ (accessed March 3, 2024).

[2] K.M. Arjun, Indian Agriculture- Status , Importance and, *International Journal of Agriculture and Food Science Technology* 4 (2013) 343–346. http://www.ripublication.com/ijafst.htm.

[3] A. Krishnan, S. Swarna, B.H. S, Robotics, IoT, and AI in the Automation of Agricultural Industry: A Review, in: 2020 IEEE Bangalore Humanitarian Technology Conference (B-HTC), IEEE, 2020: pp. 1–6. https://doi.org/10.1109/B-HTC50970.2020.9297856.

[4] H.M. Rai, M. Chauhan, H. Sharma, N. Bhardwaj, L. Kumar, AgriBot: Smart Autonomous Agriculture Robot for Multipurpose Farming Application Using IOT, in: 2022: pp. 491–503. https://doi.org/10.1007/978-981-19-0284-0_36.

[5] H.M. Rai, D. Gupta, S. Mishra, H. Sharma, Agri-Bot: IoT Based Unmanned Smart Vehicle for Multiple Agriculture Operation, in: 2021 International Conference on Simulation, Automation and Smart Manufacturing, SASM 2021, Institute of Electrical and Electronics Engineers Inc., 2021. https://doi.org/10.1109/SASM51857.2021.9841182.

[6] S. Gupta, Sharmila, H.M. Rai, IoT-Based Automatic Irrigation System Using Robotic Vehicle, in: D. Goyal, V.E. Bălaş, A. Mukherjee, V.H.C. de Albuquerque, A.K. Gupta (Eds.), Information Management and Machine Intelligence. ICIMMI 2019. Algorithms for Intelligent Systems. Springer, Springer, Singapore, 2021: pp. 669–677. https://doi.org/10.1007/978-981-15-4936-6_73.

[7] R. Sharma, N. Kumar, B.B. Sharma, Applications of Artificial Intelligence in Smart Agriculture: A Review, in: 2022: pp. 135–142. https://doi.org/10.1007/978-981-16-8248-3_11.

[8] B. Zhao, The Application of Artificial Intelligence in Agriculture, *J Phys Conf Ser* 1574 (2020) 012139. https://doi.org/10.1088/1742-6596/1574/1/012139.

[9] Y. Akkem, S.K. Biswas, A. Varanasi, Smart farming using artificial intelligence: A review, *Eng Appl Artif Intell* 120 (2023) 105899. https://doi.org/10.1016/j.engappai.2023.105899.

[10] R. Priya, D. Ramesh, ML based sustainable precision agriculture: A future generation perspective, *Sustainable Computing: Informatics and Systems* 28 (2020) 100439. https://doi.org/10.1016/j.suscom.2020.100439.

[11] A. Bouguettaya, H. Zarzour, A. Kechida, A.M. Taberkit, Deep learning techniques to classify agricultural crops through UAV imagery: a review, *Neural Comput Appl* 34 (2022) 9511–9536. https://doi.org/10.1007/s00521-022-07104-9.

[12] M. Albahar, A Survey on Deep Learning and Its Impact on Agriculture: Challenges and Opportunities, *Agriculture* 13 (2023) 540. https://doi.org/10.3390/agriculture13030540.

[13] M. Gardezi, B. Joshi, D.M. Rizzo, M. Ryan, E. Prutzer, S. Brugler, A. Dadkhah, Artificial intelligence in farming: Challenges and opportunities for building trust, *Agronomy Journal* (2023). https://doi.org/10.1002/agj2.21353.

[14] R.C. de Oliveira, R.D. de S. e Silva, Artificial Intelligence in Agriculture: Benefits, Challenges, and Trends, *Applied Sciences* 13 (2023) 7405. https://doi.org/10.3390/app13137405.

[15] V.S. Dhaka, N. Kundu, G. Rani, E. Zumpano, E. Vocaturo, Role of Internet of Things and Deep Learning Techniques in Plant Disease Detection and Classification: A Focused Review, *Sensors* 23 (2023) 7877. https://doi.org/10.3390/s23187877.

[16] D. Tirkey, K.K. Singh, S. Tripathi, Performance analysis of AI-based solutions for crop disease identification, detection, and classification, *Smart Agricultural Technology* 5 (2023) 100238. https://doi.org/10.1016/j.atech.2023.100238.

[17] Y.J. Ren, X.H. Ding, X.Y. Yang, The Application of Temperature Sensor TMP36 and the Assembly Algorithm of Multidigit Decimal Resolving, *Applied Mechanics and Materials* 130–134 (2011) 4210–4215. https://doi.org/10.4028/www.scientific.net/AMM.130-134.4210.

[18] H.K. Kondaveeti, N.K. Kumaravelu, S.D. Vanambathina, S.E. Mathe, S. Vappangi, A systematic literature review on prototyping with Arduino: Applications, challenges, advantages, and limitations, *Comput Sci Rev* 40 (2021) 100364. https://doi.org/10.1016/j.cosrev.2021.100364.

[19] S.-C. Her, S.-Z. Weng, Fiber Bragg Grating Pressure Sensor Integrated with Epoxy Diaphragm, *Sensors* 21 (2021) 3199. https://doi.org/10.3390/s21093199.

[20] SEN0257 Gravity water pressure sensor, Dfrobot (n.d.). https://wiki.dfrobot.com/Gravity__Water_Pressure_Sensor_SKU__SEN0257 (accessed March 3, 2022).

[21] J. Jiang, J. Li, H. Qiu, R. Ren, Y. Liu, Z. Zhong, R. Ye, Temperature and Humidity Acquisition Device Based on DHT11, in: 2021 2nd International Conference on Artificial Intelligence and Information Systems, ACM, New York, NY, USA, 2021: pp. 1–6. https://doi.org/10.1145/3469213.3470675.

[22] I.K.N. Trisnawan, A.N. Jati, N. Istiqomah, I. Wasisto, Detection of Gas Leaks Using The MQ-2 Gas Sensor on the Autonomous Mobile Sensor, in: 2019 International Conference on Computer, Control, Informatics and Its Applications (IC3INA), IEEE, 2019: pp. 177–180. https://doi.org/10.1109/IC3INA48034.2019.8949597.