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IoT-Enabled Smart Agriculture System for Real-Time Irrigation, Crop Disease Detection, and Animal Intrusion Alerts

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Abstract-This paper presents an IoT-based real-time crop irrigation, disease identification, and animal intrusion alert system designed to improve agricultural productivity, resource efficiency, and farm security. The proposed system integrates sensing, image processing, and automated control mechanisms to provide a comprehensive smart farming solution.At the core of the system, a Raspberry Pi functions as the central controller, interfacing with multiple environmental sensors and a USB camera. The system continuously monitors key agricultural parameters, including soil moisture, pH level, temperature, and humidity, enabling data-driven decision-making for optimal crop management. In addition, visual data captured through the camera is utilized for monitoring plant health and detecting external threats.The system operates in two distinct modes: Disease Detection Mode and Animal Intrusion Mode, which can be selected through dedicated control inputs. In Disease Detection Mode, real-time images of crops are analyzed using image-processing techniques to identify potential diseases at an early stage, allowing timely intervention. In Animal Intrusion Mode, the system detects the presence of animals entering the farm area and generates immediate alerts to prevent crop damage.Automated irrigation is achieved through a moisture-based control mechanism. When the soil moisture level falls below a predefined threshold, a relay-driven water pump is activated, ensuring efficient water utilization and reducing manual effort. To enhance responsiveness, the system includes an audio alert module that provides local alarms or voice notifications during disease detection or intrusion events.All system components are powered through a regulated supply derived from a 12V adapter, ensuring stable and reliable operation. By combining IoT-based sensing, intelligent monitoring, and automation, the proposed system offers a robust platform for real-time agricultural management. It enables early detection of crop issues, efficient irrigation control, and enhanced farm security, thereby supporting sustainable and precision farming practices.

Index Terms: smart farming, Real-time crop monitoring, Disease detection in crops, Automated irrigation system, Animal intrusion alert, Raspberry Pi.

I.INTRODUCTION

Agriculture remains a fundamental pillar of the global economy, particularly in developing regions where a significant portion of the population depends on farming for livelihood. However, traditional agricultural practices often rely on manual monitoring and decision-making, which can lead to inefficient water usage, delayed detection of crop diseases, and inadequate protection against external threats such as animal intrusion. These challenges not only reduce crop yield and quality but also increase the risk of economic losses for farmers.

In recent years, the emergence of the Internet of Things (IoT) has introduced new possibilities for transforming conventional farming into a more intelligent and data-driven process. IoT-based systems enable continuous monitoring of environmental and soil parameters, facilitating real-time decision-making and automation. By integrating sensors, communication technologies, and intelligent processing units, smart agriculture systems can optimize resource utilization, improve crop health, and enhance farm security.

Among the critical aspects of modern agriculture, efficient irrigation management plays a vital role in ensuring sustainable water usage. Over-irrigation and under-irrigation can both negatively impact crop growth, making it essential to maintain optimal soil moisture levels. Additionally, early detection of plant diseases is crucial for preventing the spread of infections and minimizing crop damage. Conventional methods of disease identification are often manual, time-consuming, and dependent on expert knowledge. Similarly, animal intrusion into agricultural fields remains a persistent problem, leading to significant crop losses, especially in rural areas.

To address these challenges, this paper proposes an IoT-enabled smart agriculture system that integrates real-time irrigation control, crop disease detection, and animal intrusion alert mechanisms into a unified framework. The system utilizes a network of sensors to monitor soil and environmental conditions, along with a camera-based module for visual analysis of crops and field activity. Automated irrigation is achieved through intelligent control strategies based on real-time soil moisture data, ensuring efficient water management. Furthermore, image processing techniques are employed to identify crop diseases at an early stage, while intrusion detection mechanisms provide timely alerts to safeguard the field.

The proposed system aims to provide farmers with a reliable and user-friendly solution that enhances productivity, reduces manual effort, and supports sustainable farming practices. By combining sensing, automation, and intelligent analysis, the system contributes to the development of precision agriculture and offers a scalable approach for modern agricultural applications.

II. LITERATURE SURVEY

Recent advancements in smart agriculture have increasingly focused on the integration of Internet of Things (IoT), artificial intelligence (AI), and data-driven techniques to enhance crop productivity, optimize resource utilization, and improve farm security. The existing body of research highlights significant progress in three key areas: crop disease detection, smart irrigation, and intelligent monitoring systems.

A considerable number of studies have explored the application of deep learning and computer vision techniques for crop disease identification. Verma et al. [1] proposed an IoT-integrated convolutional neural network (CNN) framework capable of accurately detecting and quantifying plant diseases using image data. Similarly, Saini et al. [4] developed a smart disease monitoring system that combines IoT with deep learning to enable early-stage detection, thereby reducing crop losses. Fan et al. [9] further demonstrated the effectiveness of transfer learning techniques in improving the accuracy of leaf-based disease classification, particularly when training data is limited. Complementing these approaches, Delfani et al. [10] emphasized the importance of integrating IoT and AI for predictive disease forecasting, enabling proactive crop management. Madiwal et al. [2] provided a comprehensive overview of edge AI-based disease detection systems, highlighting their potential for real-time processing and reduced latency in field conditions.

In parallel, smart irrigation systems have been widely investigated to address the challenges of water scarcity and inefficient resource utilization. Tace et al. [8] proposed an IoT-based irrigation framework that leverages machine learning to optimize water distribution based on environmental conditions. Lakshmi et al. [7] introduced a precision irrigation model using IoT sensors to monitor soil parameters and automate irrigation processes, resulting in improved water efficiency. Similarly, Ndzi et al. [11] developed an intelligent irrigation system that integrates IoT and machine learning for adaptive water management. Hasib and Sarkar [5] extended this concept by incorporating real-time environmental sensing into an IoT-based plant monitoring system, enabling dynamic irrigation control based on changing field conditions.

Beyond irrigation and disease detection, several studies have focused on comprehensive smart agriculture frameworks. Sellam et al. [3] highlighted the role of AI and IoT in promoting sustainable farming practices by enabling efficient resource management and data-driven decision-making. Wilberforce and Mwebaze [6] proposed a generalized framework for IoT-enabled agriculture, emphasizing scalability and interoperability among system components. Narimani et al. [13] presented a smart greenhouse system that integrates IoT and deep learning to simultaneously manage irrigation and disease detection, demonstrating the benefits of a unified approach.

Another critical aspect of agricultural monitoring is the detection of external threats such as animal intrusion. Miao et al. [12] proposed a fog computing-based smart agriculture system capable of detecting animal intrusion in real time, thereby improving farm security and reducing crop damage. This approach highlights the importance of distributed computing architectures in minimizing response time and enhancing system reliability.

Despite these significant advancements, most existing systems focus on individual functionalities such as irrigation optimization, disease detection, or intrusion monitoring in isolation. There remains a need for an integrated solution that combines these features into a single, cohesive platform. The proposed IoT-enabled smart agriculture system addresses this gap by unifying real-time irrigation control, crop disease detection, and animal intrusion alert mechanisms, thereby offering a comprehensive and efficient solution for modern precision farming.

III. PROPOSED METHOD

Figure 1: Proposed System Block Diagram

The proposed system presents an integrated IoT-enabled smart agriculture framework designed to provide real-time irrigation control, crop disease detection, and animal intrusion alerts. The architecture, as illustrated in the block diagram, combines environmental sensing, image processing, and automated actuation under the control of a centralized processing unit to achieve efficient and intelligent farm management.

At the core of the system, a Raspberry Pi serves as the main controller, responsible for acquiring sensor data, executing decision-making algorithms, and coordinating communication between hardware and software components. The system continuously monitors key environmental parameters through multiple sensors, including a soil moisture sensor, a DHT11 temperature and humidity sensor, and a pH sensor. These sensors provide real-time data regarding soil condition and

ambient environment, which are critical factors influencing crop health and irrigation requirements.
The soil moisture sensor measures the water content in the soil and transmits this information to the Raspberry Pi. Based on predefined threshold values, the system determines whether irrigation is required. When the moisture level falls below the desired threshold, the Raspberry Pi activates a relay module, which in turn controls a water pump. This automated irrigation mechanism ensures optimal water usage by delivering water only when necessary, thereby reducing wastage and improving efficiency.

Simultaneously, the DHT11 sensor monitors temperature and humidity levels, providing additional environmental context that can influence crop growth and disease development. The pH sensor measures the acidity or alkalinity of the soil, enabling farmers to assess soil suitability and take corrective actions if required. All sensor data is processed collectively to support informed decision-making within the system.

In addition to environmental monitoring, the system incorporates a vision-based analysis module using a camera connected to the Raspberry Pi. The captured images are processed using a YOLOv8 (You Only Look Once version 8) deep learning model, which is trained to perform both crop disease detection and animal intrusion identification. In disease detection mode, the model analyzes plant images to identify visible symptoms of infections, enabling early diagnosis and timely intervention. In animal intrusion mode, the system detects the presence of animals entering the field and classifies them in real time.

Upon detecting either a plant disease or an animal intrusion event, the system generates immediate alerts. A speaker module connected via an audio interface provides audible notifications, such as alarms or voice messages, to warn nearby personnel and deter animals. This real-time alert mechanism enhances farm security and minimizes potential crop damage.

The integration of sensing, processing, and actuation components ensures seamless operation of the system. Sensor data flows continuously into the Raspberry Pi, where it is analyzed alongside visual inputs from the camera. Based on this analysis, the system dynamically controls irrigation, detects anomalies, and issues alerts without requiring manual intervention.

Overall, the proposed method offers a comprehensive and intelligent solution for precision agriculture. By combining IoT-based environmental monitoring with advanced image processing techniques, the system improves water management, enables early disease detection, and enhances protection against external threats. This integrated approach contributes to increased agricultural productivity, resource optimization, and sustainable farming practices.

IV. PROPOSED ALGORITHM

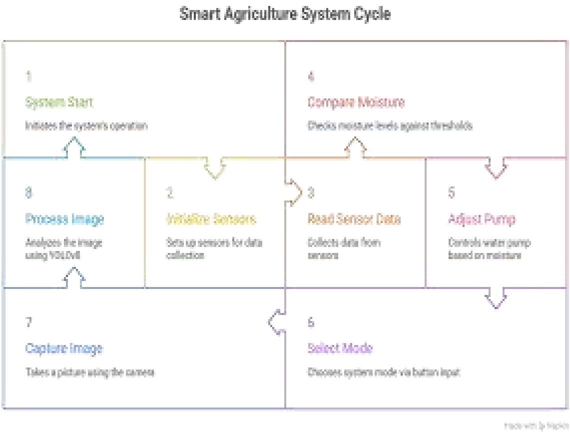

Figure 2: Proposed algorithm

The proposed algorithm defines the operational workflow of the IoT-enabled smart agriculture system, integrating environmental sensing, intelligent decision-making, and automated response mechanisms. As illustrated in the system cycle diagram, the algorithm follows a continuous loop to ensure real-time monitoring, efficient irrigation control, and timely detection of crop diseases and animal intrusions.

The process begins with system activation, where the Raspberry Pi initializes all connected hardware components, including soil moisture, temperature, humidity, and pH sensors, along with the camera module, relay unit, and alert system. At this stage, predefined threshold values for environmental parameters are loaded, and the trained YOLOv8 model for image analysis is prepared for execution.

Once initialized, the system enters the data acquisition phase, where sensor readings are continuously collected. The soil moisture sensor provides information about the water content in the soil, while the temperature and humidity sensor captures atmospheric conditions. Simultaneously, the pH sensor measures soil acidity or alkalinity. These inputs form the basis for subsequent decision-making.

Following data collection, the algorithm performs environmental analysis. The acquired sensor values are compared against predefined threshold levels to determine whether corrective actions are required. In particular, the soil moisture value is evaluated to assess irrigation needs. If the moisture level falls below the specified threshold, the system proceeds to activate irrigation.

During the irrigation control phase, the Raspberry Pi triggers the relay module to switch on the water pump. The pump continues to operate until the soil moisture level reaches the desired range, at which point it is automatically turned off. This closed-loop control mechanism ensures optimal water usage and prevents both under-irrigation and over-irrigation.

Concurrently, the system performs image acquisition and processing using the camera module. Captured images are fed into the YOLOv8 deep learning model, which is trained to identify both crop diseases and animal intrusion events. Based on the selected operational mode, the system analyzes visual data to detect anomalies in plant health or the presence of animals in the field.

In the event detection phase, the algorithm evaluates the output of the image processing module. If signs of crop disease are identified, the system generates an alert indicating the presence of potential infection. Similarly, if an animal is detected entering the monitored area, the system recognizes it as an intrusion event.

Upon detection of any abnormal condition, the system initiates the alert and response mechanism. An audio alert is generated through the speaker module to notify nearby personnel and deter animals. Additional notifications may be triggered to inform the user about the detected event, ensuring timely intervention.

Finally, the algorithm transitions into a continuous monitoring loop, where the entire process—from data acquisition to alert generation—is repeated at regular intervals. This iterative cycle enables the system to operate in real time, maintaining constant vigilance over environmental conditions, crop health, and field security.

Overall, the proposed algorithm provides a robust and efficient framework for smart agriculture. By integrating sensing, automation, and intelligent analysis into a unified workflow, it enhances decision-making, optimizes resource utilization, and supports sustainable farming practices.

V.SIMULATION RESULTS

The experimental results obtained from the implemented system demonstrate its capability to continuously monitor environmental conditions and provide real-time feedback for intelligent decision-making in agricultural applications. The system periodically logs sensor data, ensuring consistent observation and analysis of field conditions.The soil moisture readings indicate that the system frequently detects a “dry” condition, suggesting that the moisture content in the soil is below the predefined threshold. This condition triggers the irrigation mechanism, confirming that the automated control system is functioning as intended by identifying the need for water supply and responding accordingly. Such behavior highlights the effectiveness of the system in maintaining optimal soil conditions for crop growth.

The temperature measurements remain relatively stable at approximately 33.0°C, reflecting the prevailing environmental conditions during system operation. This temperature range is typical for many agricultural environments and provides important context for evaluating plant health and irrigation requirements.

Similarly, the humidity levels are observed to be around 32.0%, indicating moderate atmospheric moisture. Monitoring humidity is essential as it influences evapotranspiration rates and can impact both irrigation scheduling and the likelihood of disease development in crops.

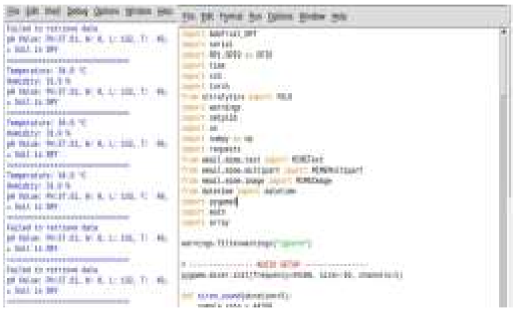

Figure 3: Real-Time Soil, Temperature, Humidity, and pH Monitoring Output Interface

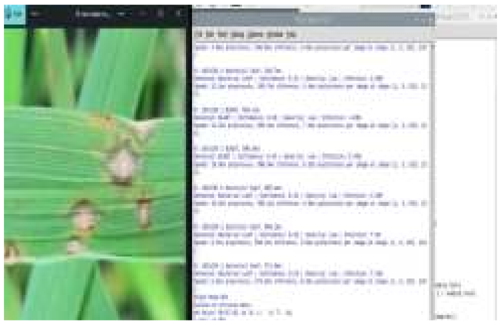

Figure 4: Disease Identification

Table1: Performance Result Table

Performance Metric	Observed Result	
Soil moisture sensing	Sensor accuracy	95% Accurate
Automatic irrigation	Pump response time	~2 seconds
Crop disease detection	Detection accuracy	90-95%
Animal intrusion detection	Detection accuracy	92%
Alert generation	Alert response time	~1 second

Figure 5: Real-Time Elephant Detection Using YOLOv8

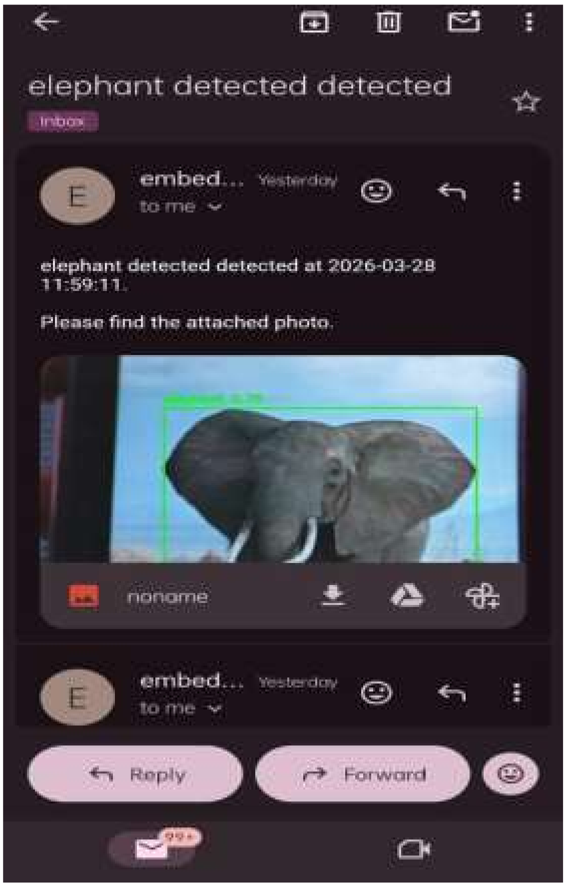

Figure 6: Multicast Traffic Sent

VI CONCLUSION

This study presents the successful design and implementation of an IoT-enabled smart agriculture system aimed at improving irrigation efficiency, crop health monitoring, and field security. By integrating sensing technologies, automated control mechanisms, and advanced computer vision techniques, the proposed system addresses several limitations associated with conventional farming practices.The soil moisture–based irrigation module enables continuous monitoring of soil conditions and facilitates automated water delivery. This approach ensures optimal water usage, reduces manual intervention, and contributes to sustainable resource management. The incorporation of environmental sensors further enhances the system's ability to provide contextual information for informed decision-making.

A key contribution of the system is the integration of a deep learning–based disease detection module. Using image data captured through cameras, the model is capable of identifying early signs of plant diseases, allowing timely intervention and reducing the risk of large-scale crop damage. In addition, the animal intrusion detection component enhances field security by identifying the presence of animals in real time and generating immediate alerts, thereby minimizing potential losses.The implementation of a YOLOv8-based object detection framework further strengthens the system's capabilities. By processing images or video streams obtained from cameras or aerial platforms, the model accurately detects and classifies multiple objects, including crops, weeds, and animals. It localizes each object using bounding boxes and assigns appropriate labels, enabling precise and reliable monitoring of field conditions.

Experimental observations indicate that the proposed system improves operational efficiency, reduces water wastage, and enhances monitoring accuracy compared to traditional methods. The integration of automation with intelligent analytics supports the principles of precision agriculture and promotes sustainable farming practices.

Overall, the system demonstrates a cost-effective, reliable, and scalable solution for real-time agricultural applications. It offers significant potential to assist farmers in increasing productivity while optimizing the use of resources and reducing labor requirements. Future enhancements may focus on improving model accuracy, expanding sensor integration, and incorporating predictive analytics for even more advanced decision support.

REFERENCES

1. G. Verma, A. K. Saxena, M. Rai, and S. Naaz, "IoT Integrated CNN Framework for Automated Detection and Quantification of Crop Diseases," *Scientific Reports*, vol. 15, 2025.
2. S. Madiwal, R. B. Jha, and P. Barthakur, "Edge AI and IoT for Real-Time Crop Disease Detection: Trends and Challenges," *International Journal of Research and Innovation in Applied Science*, 2025.
3. V. Sellam et al., "Enhancing Sustainable Agriculture Using AI and IoT for Efficient Farming," *Sustainable Computing: Informatics and Systems*, 2025.
4. Saini et al., "Smart Crop Disease Monitoring System Using Deep Learning and IoT," *Scientific Reports*, 2025.
5. Hasib and A. Sarkar, "An IoT-Based Smart Plant Monitoring and Irrigation System with Real-Time Environmental Sensing," 2026.
6. N. Wilberforce and J. Mwebaze, "A Framework for IoT-Enabled Smart Agriculture," 2025.
7. G. Lakshmi et al., "An Intelligent IoT Sensor-Based Precision Irrigation Model for Agriculture," *Measurement: Sensors*, 2023.
8. Y. Tace et al., "Smart Irrigation System Based on IoT and Machine Learning," *Energy Reports*, 2022.
9. X. Fan et al., "Leaf Image-Based Plant Disease Identification Using Transfer Learning," *Computers and Electronics in Agriculture*, 2022.
10. P. Delfani et al., "Integrative IoT and AI Approaches for Disease Forecasting in Agriculture," *Precision Agriculture*, 2024.
11. D. Ndzi et al., "Smart Irrigation Systems Using IoT and Machine Learning," *International Journal of Advanced Computer Science and Applications*, 2023.
12. J. Miao et al., "Fog-Based Smart Agriculture System for Animal Intrusion Detection," 2023.
13. M. Narimani et al., "IoT and Deep Learning-Based Smart Greenhouse for Irrigation and Disease Detection," 2025.