DAYANANDA SAGAR UNIVERSITY

**KUDLU GATE, BANGALORE – 560068**



**Bachelor of Technology   
  
in**

**COMPUTER SCIENCE AND TECHNOLOGY**

**Project Phase-II Report**

**(20CT4802)**

**IoT-Enhanced Tomato plant cultivation with machine learning**

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**CERTIFICATE**

This is to certify that the work titled **“ IoT-Enhanced Tomato plant cultivation with machine learning”** is carried out by **Abhas Agnihotri (ENG20CT0001), Deepak B G (ENG20CT0009), M Nikhil Guptha (ENG20CT0015), Shashikala M S (ENG20CT0025)** Bonafide students of Bachelor of Technology in Computer Science and Technology at the School of Engineering, Dayananda Sagar University, Bangalore in partial fulfillment for the award of degree in Bachelor of Technology in Computer Science and Technology, during the year **2023-2024**.

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**DECLARATION**

WeAbhas Agnihotri (ENG20CT0001), Deepak B G (ENG20CT0009), M Nikhil Guptha (ENG20CT0015), Shashikala M S (ENG20CT0025) ,are students of the seventh semester B.Tech in Computer Science and Technology, at School of Engineering, Dayananda Sagar University, hereby declare that the project phase-II project titled “ IoT-Enhanced Tomato plant cultivation with machine learning ” has been carried out by us and submitted in partial fulfillment for the award of degree in Bachelor of Technology in Computer Science and Technology during the academic year 2023-2024.

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**ACKNOWLDENEMENT**

*It is a great pleasure for us to acknowledge the assistance and support of many individuals who have been responsible for the successful completion of this project work.*

*First, we take this opportunity to express our sincere gratitude to School of Engineering, Dayananda Sagar University for providing us with a great opportunity to pursue our Bachelor’s degree in this institution.*

*We would like to thank* ***Dr. Udaya Kumar Reddy K R, Dean, School of Engineering & Technology, Dayananda Sagar University*** *for his constant encouragement and expert advice.*

*It is a matter of immense pleasure to express our sincere thanks to* ***Dr. M Shahina Parveen, Chairperson****,* ***Computer Science and Technology****,* ***Dayananda Sagar University,*** *for providing right academic guidance that made our task possible.*

*We would like to thank our* ***Project Coordinator Dr. Bhaskar Venugopalan*** *and* ***Prof. Chithambarathanu M*** *as well as all the staff members of Computer Science and Technology for their support. We are also grateful to our family and friends who provided us with every requirement throughout the course.*

*We would like to thank our guide* ***Prof*** ***Nivetha NRP****,* ***Assistant Professor****,* ***Dept. of Computer Science and Engineering****,* ***Dayananda Sagar University****, for sparing her valuable time to extend help in every step of our project work, which paved the way for smooth progress and fruitful culmination of the project.*

*We would like to thank one and all who directly or indirectly helped us in the Project work.*

**ABSTRACT**

The integration of IoT and machine learning in tomato cultivation marks a significant advancement, addressing critical challenges in soil moisture monitoring, nutrient management, and pest detection. These aspects are pivotal for maximizing crop yield and sustainability. Through IoT-enabled sensors like soil moisture and NPK sensors connected to microcontrollers such as NodeMCU and Arduino Uno, real-time data on soil conditions and nutrient levels are gathered. This data empowers farmers with actionable insights for timely interventions and efficient resource allocation.

Key functionalities of this integrated system include dynamic soil moisture detection and regulation, ensuring optimal hydration levels throughout various plant growth stages. Additionally, the system facilitates precise soil nutrient management through NPK sensors and RS485 modules, offering valuable insights for nutrient optimization strategies. Furthermore, pest detection is enhanced using a camera module and ML model, enabling accurate identification of diseases and pests. This capability allows for proactive pest management measures, contributing to improved crop health and productivity.

This holistic approach represents a significant step towards modernizing agricultural practices, emphasizing sustainability, efficiency, and productivity in tomato cultivation. The scalable solutions offered by this integrated system have the potential to enhance overall crop management and contribute significantly to food security initiatives.

**Keywords: Internet of Things (IoT), Convolutional Neural Network (CNN), InceptionV3, Soil Moisture Monitoring, Soil Nutrient Management, Pest Detection.**

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**CHAPTER 1**

**INTRODUCTION**

Tomato cultivation is a vital component of global agriculture, contributing significantly to food production, economic stability, and food security. In recent years, there has been a growing emphasis on adopting advanced technologies to enhance agricultural practices, particularly in the context of optimizing crop yield, quality, and sustainability. This introduction delves into the transformative potential of integrating Internet of Things (IoT) devices and machine learning (ML) algorithms in tomato cultivation, focusing on soil moisture monitoring, nutrient management, and pest detection.

**1.1 Soil Moisture Monitoring and Automated Pumping**

Soil moisture is a critical factor influencing plant growth, nutrient uptake, and overall crop health. In traditional farming, manual soil moisture assessment and irrigation practices often result in water wastage or inadequate hydration for plants. The introduction of IoT-based soil moisture monitoring systems has transformed this aspect of agriculture. These systems employ advanced sensors capable of accurately measuring soil moisture levels in real-time. By continuously monitoring soil moisture, farmers can optimize irrigation schedules, ensuring that plants receive the right amount of water at the right time. This not only conserves water but also promotes healthy root development, reduces water stress, and enhances crop resilience to environmental fluctuations.

**1.2 Soil Nutrient Management**

Nutrients such as Nitrogen (N), Phosphorus (P), and Potassium (K) are essential for plant growth, flowering, fruiting, and overall productivity. Imbalances or deficiencies in these nutrients can lead to stunted growth, nutrient-related disorders, and reduced crop yields. Traditional nutrient management practices often rely on manual observation or generalized fertilization schedules, which may not meet the specific needs of different crops or growth stages. IoT-enabled nutrient management systems address this challenge by integrating NPK sensors that monitor nutrient levels in the soil. By delivering the right nutrients in the right quantities, IoT-based nutrient management enhances plant vigor, optimizes yield potential, and minimizes nutrient wastage.

**1.3 Pest Detection and Management**

Pests and diseases pose significant threats to crop health and yield. Traditional pest management approaches rely heavily on pesticide applications, which can be costly, environmentally harmful, and sometimes ineffective due to improper timing or dosage. IoT and ML technologies offer a more sustainable and proactive approach to pest detection and management. ML algorithms trained on image data can accurately identify pest infestations, leaf diseases, and other abnormalities in crops. Integrated with IoT systems, these ML models can trigger automated alerts or responses when pests or diseases are detected. By enabling early detection and targeted interventions, IoT-based pest management systems reduce reliance on chemical pesticides, minimize crop damage, and promote ecological balance in agricultural ecosystems.

Overall, the integration of IoT, ML, and advanced sensors in tomato cultivation represents a paradigm shift towards precision agriculture. These technologies empower farmers with real-time data insights, automation capabilities, and decision support tools, enabling them to optimize resource usage, improve crop quality, and sustainably meet the growing demand for food globally.

**CHAPTER 2**

**LITERATURE REVIEW**

**1. IoT-Enabled Smart Drip Irrigation System Using ESP3,2023**

*Journal*MDPI

*Authors*Gilroy P. Pereira, Mohamed Z. Chaari, and Fawwad Daroge

*Problem mentioned*

This paper introduces a Smart Drip Irrigation System to address the challenge of efficient water management in agriculture. The solution is an IoT-enabled system that automates irrigation based on soil moisture, temperature, and humidity, optimizing water usage for plant growth.

*Tools Used*

1. Microcontroller: ESP32
2. Moisture Sensor: DFRobot SEN0308
3. Temperature Sensor: DS18B20
4. Air Humidity Sensor: DHT22
5. Water Flow Sensor: FS300A G3/4 Inch
6. Solenoid Valve: Hunter PGV-100G (24VAC)
7. Relay: Used as an electrically controlled switch
8. Step-Down Voltage Regulator: To supply power to the ESP32
9. Acrylic Container: Custom-made for housing the system
10. Soil: All-purpose potting soil with specific characteristics.

*Results and Discussion*

Primary tests in the laboratory validated the functionality of various sensors, solenoid valve, and firmware. Comparison of sensor readings to weather forecasts demonstrated accurate measurements, particularly in air temperature and humidity. Outdoor testing of the solenoid valve confirmed the system's effectiveness in an outdoor environment. Field testing of the smart drip irrigation system showcased successful growth of spring onions, ensuring adequate water supply and automated irrigation based on sensor readings.

*Knowledge Acquired*

The paper provides insights into building an IoT-enabled smart drip irrigation system for precision agriculture, emphasizing automation and control using a microcontroller. It discusses calibration, sensor validation, and field testing, offering real-time monitoring and control through a Blynk IoT dashboard.

**2. A Literature Review on Automatic Watering of Plants,2022**

*Journal/Conference*

IJCRT

*Author*Mani Bansal, Abhay Pandey, Mandvi Singh, Nivesh Sharma, Ms. Neha, Raj Kumar Goel

*Problem Statement and Solution*

In this literature review, we explore the challenges associated with manual plant watering and the benefits of implementing automatic plant watering systems. The problem lies in the time and effort required for regular plant care, especially in a world where people have increasingly busy lives. The solution obtained involves investigating various automatic plant watering systems and assessing their effectiveness, cost-efficiency, and impact on plant health.

*Algorithm Used*

This literature review does not directly involve the use of algorithms since it primarily focuses on summarizing and analyzing existing research. However, some of the automatic plant watering systems discussed in the review may employ algorithms for soil moisture measurement and water delivery.

*Tools Used*

1. Soil moisture sensors
2. Microcontrollers (e.g., Arduino)
3. Water pumps
4. Solenoid valves
5. Cloud-based monitoring
6. control systems

*Result and Discussion*

The results section will summarize the key findings from the literature review. These findings may include the benefits of automatic watering, such as improved plant health and reduced water usage. It may also discuss the limitations and challenges associated with certain systems. The discussion section will provide insights into the implications of the results and highlight any gaps in the existing research.

*Knowledge Acquired*

The knowledge acquired from this literature review encompasses a comprehensive understanding of the state of the art in automatic plant watering systems. Readers will gain insights into the advantages and disadvantages of various approaches, the impact on plant growth, and the potential for widespread adoption of such systems.

**3. Monitoring of Soil Nutrients Using Soil NPK Sensor and Arduino, 2023**

*Journal*

Ecology, Environment and Conservation Journal

*Author*

• G. L. Lenin Kumar

• M. Srivani

• Md. Tabassum Nishath

• T. Akhil • Arugula Naveen

• K. Charith Kumar

*Problem mentioned*

The paper addresses the challenge of accurately monitoring soil nutrients in agricultural fields, crucial for optimizing crop yield and ensuring sustainable farming practices. It proposes the integration of a Soil NPK Sensor with Arduino technology as a solution to provide real-time data on essential nutrients – nitrogen, phosphorus, and potassium – in the soil. By utilizing this sensor-based approach, the study aims to overcome the limitations of traditional soil testing methods, which are often time-consuming, labor-intensive, and costly.

*Tools Used*

1. Soil NPK Sensor: A 3-in-1 fertility sensor designed to detect the content of nitrogen, phosphorus, and potassium in the soil with high precision and accuracy.
2. Arduino Technology: The Arduino platform is utilized to interface with the soil NPK sensor, enabling data collection and analysis in real-time.
3. MAX485 TTL to RS485 Converter Module: This module facilitates communication between the Arduino board and the soil NPK sensor via RS485 protocol.
4. OLED Display Module: A monochrome OLED display is used to visualize the sensor data, providing an intuitive interface for users.

*Results and Discission*

The research conducted experiments at various data points to evaluate the performance of the soil NPK sensor integrated with Arduino technology. The results indicate that the sensor system provides nutrient levels (NPK) in soil that closely match values obtained from laboratory measurements. This suggests that the sensor-based approach offers high accuracy and efficiency in monitoring soil nutrients, making it a cost-effective solution for continuous soil nutrient monitoring in agricultural fields.

**4. Field application of precise IoT-based soil testing and fertilizer recommendation system in tomato, 2023**

*Journal*

The Pharma Innovation Journal

*Authors*

Bijaylakhmi Goswami and Naseema Rahman

*Problem mentioned*

The paper discusses the challenges faced in traditional soil testing and fertilizer recommendation methods for tomato cultivation. It presents a solution through the implementation of an IoT-based system that offers precise soil testing and personalized fertilizer recommendations tailored to the specific needs of tomato plants. This approach aims to optimize nutrient utilization, improve yield, and enhance overall crop quality.

*Algorithm Used*

The paper incorporates advanced algorithms for data analysis and decision-making within the IoT-based system. Details regarding the algorithms used will be elaborated in the methodology section.

*Tools Used/Implemented*

The implementation of the IoT-based soil testing and fertilizer recommendation system includes a mix of hardware and software tools. These tools encompass sensors for soil parameter measurement, data processing units, communication modules for IoT connectivity, and software for data analysis and recommendation generation.

*Results and Discussion*

The results of the study demonstrate significant improvements in tomato yield and quality through the implementation of the IoT-based soil testing and fertilizer recommendation system compared to traditional methods. Quantitative data analysis reveals a notable increase in yield per hectare, with an average of 20% higher yield observed across multiple test plots. This increase is attributed to the system's ability to precisely monitor soil nutrient levels and provide tailored fertilizer recommendations, leading to optimized nutrient utilization by tomato plants. Additionally, the IoT system contributes to better resource management by reducing fertilizer usage by 15% on average while maintaining or even enhancing crop productivity. This reduction in fertilizer application not only results in cost savings for farmers but also contributes to environmental sustainability by minimizing nutrient runoff and potential soil degradation.

*Knowledge Acquired*

Through the research and implementation of the IoT-based system, valuable insights into optimizing tomato cultivation practices using technology are gained. This includes understanding the importance of real-time data monitoring.

**5. A review on the seasonal succession and management of key insect pests infesting tomatoes**, **2023**

*Journal*

IEEEInternational Conference on Image Processing (ICIP)

*Author*

Soniya Dhanda

Surender Singh Yadav

Anil Jakhar

Sonu Kumari

*Problem mentioned*

The paper addresses the challenge of accurately segmenting medical images, particularly in the context of tumor detection. It compares various image segmentation algorithms to identify the most effective approach for medical image analysis.

*Algorithm Used*

The paper evaluates several segmentation algorithms, including K-means clustering, Watershed transform, and Convolutional Neural Networks (CNNs).

*Tools Used*

MATLAB, Python with TensorFlow and Keras for implementing CNNs.

*Results and Discussion*

The results demonstrate that CNN-based approaches outperform traditional methods like K-means clustering and Watershed transform in terms of segmentation accuracy and robustness, especially in complex medical images with varying levels of noise and artifacts. The paper discusses the strengths and limitations of each algorithm and provides insights into their performance metrics

*Knowledge Acquired*

Through this study, researchers gained a deeper understanding of the strengths and weaknesses of different image segmentation algorithms for medical image analysis. They acquired knowledge about the importance of selecting appropriate algorithms based on the characteristics of the images and the specific requirements of the medical application. Additionally, they gained insights into the potential of CNNs for improving segmentation accuracy in challenging medical imaging tasks.

**6. Deep Feature Extraction for Detection of Tomato Plant Diseases and Pests based on Leaf Images**, **2021**

*Journal*

Celal Bayar University Journal of Science.

*Author*

Yahya Altuntaş,

Adnan Fatih Kocamaz.

*Problem mentioned*

The paper addresses the challenge of detecting tomato plant diseases and pests accurately and efficiently to prevent yield and quality losses in agriculture. Traditional methods of visual observation by experts are labor-intensive and prone to errors. The authors propose a solution using deep learning techniques, specifically utilizing pre-trained convolutional neural network (CNN) models as feature extractors and a support vector machine (SVM) classifier. By extracting deep features from leaf images and training the classifier, the system achieves high accuracy in classifying different diseases and pests affecting tomato plants.

*Algorithm Used*

The study employs pre-trained CNN models (AlexNet, GoogLeNet, and ResNet-50) as feature extractors and an SVM classifier for training and classification tasks.

*Tools Used*

The experiments are conducted using the MATLAB 2019b programming environment. The dataset used for training and testing is a subset of the PlantVillage dataset containing images of diseased and healthy tomato leaves.

*Results and Discussion*

The experimental results demonstrate promising outcomes, with the proposed method achieving an overall accuracy rate of 96.99% in detecting tomato plant diseases and pests. Comparison with related studies in the literature indicates the superiority of the proposed approach. The authors discuss the implications of their findings and highlight the potential for further research to enhance classification performance and evaluate models under field conditions.

*Knowledge Acquired*

The paper provides valuable insights into the application of deep learning techniques for agricultural purposes, particularly in the domain of plant disease and pest detection. It underscores the importance of leveraging advanced technologies to address significant challenges in agriculture, ultimately contributing to food security.

**CHAPTER 3**

**REQUIREMENT SPECIFICATIONS**

**3.1. Soil Moisture Monitoring and Pumping Tools**

**3.1.1. AB054 Soil Moisture Sensor**

The AB054 Soil Moisture Sensor is a capacitive type sensor designed for monitoring soil moisture levels in agricultural applications. It operates within a voltage range of 3.3V to 5V and provides an analog output that is proportional to the moisture content in the soil. This sensor is known for its accuracy and typically covers a sensing range from 0% to 100%. It interfaces with microcontrollers like the NodeMCU, making it suitable for integration into IoT-based projects.

**3.1.2. Microcontroller (NodeMCU)**

The NodeMCU microcontroller is based on the ESP8266 chip and features a built-in Wi-Fi module, allowing for wireless data transfer. Operating at 3.3V DC, the NodeMCU is compatible with the Arduino IDE for programming and offers multiple GPIO pins for sensor interfacing. It serves as the central processing unit in the system, collecting data from the soil moisture sensor and controlling the water pump based on the moisture readings.

**3.1.3. Water Pump**

The water pump is an electric pump that operates at either 12V or 24V DC, delivering water into the soil based on commands from the NodeMCU. It is essential for maintaining optimal soil moisture levels and ensuring proper hydration of plants. The pump's flow rate and pressure rating determine its performance in pushing water through the irrigation system.

**3.1.4. Relay Module**

The relay module acts as a switch for high-voltage devices using low-voltage signals from the NodeMCU. It is compatible with 3.3V or 5V DC and has a specified switching capacity, usually around 220V AC and 10A. The relay module controls the operation of the water pump, turning it on or off as per the moisture level thresholds set in the system.

**3.1.5. Blynk**

Blynk is a mobile and web application platform designed for IoT projects. It provides real-time monitoring and control capabilities, allowing users to remotely monitor soil moisture levels and pump status. With customizable widgets and an intuitive interface, Blynk facilitates easy data visualization and management, enabling users to set thresholds and data regarding the soil moisture levels and irrigation system status.

**3.2. Soil Nutrients Detection Tools**

**3.2.1. NPK Sensor**

This specialized sensor is designed to measure the concentrations of nitrogen (N), phosphorus (P), and potassium (K) within the soil. It employs advanced technology to provide precise and reliable readings of these essential nutrients, facilitating effective nutrient management for optimal plant growth and development.

**3.2.2. Voltage Regulator:**

The voltage regulator is a vital component that ensures a stable and consistent power supply to the NPK sensor, Arduino Uno, LCD screen. By regulating the voltage output, it prevents fluctuations in power that could otherwise affect the accuracy and reliability of the sensor's readings. This stable power source is essential for obtaining accurate nutrient level data over time.

**3.2.3. RS485 module**

The RS485 module acts as a communication bridge between the NPK sensor and the Arduino Uno microcontroller. It facilitates the transmission of data from the NPK sensor, which operates on a different communication protocol, to the Arduino Uno, which processes and interprets this data.

**3.2.4. Arduino Uno:**

Serving as the intermediary between the NPK sensor and the NodeMCU, the Arduino Uno microcontroller plays a crucial role in data acquisition and processing. It receives raw data from the sensor, processes it into usable information, and prepares it for transmission to the NodeMCU. Its processing capabilities enable efficient handling of nutrient level data, contributing to the overall functionality of the system.

**3.2.5. NodeMCU (Same as Soil Moisture Monitoring):**

Similar to its role in Soil Moisture Monitoring, the NodeMCU functions as the central processing unit for soil nutrient data. It receives processed data from the Arduino Uno, performs further computations or analyses based on predefined thresholds or user-defined parameters, and initiates actions as necessary. Its connectivity features and processing power make it a key component in managing and utilizing soil nutrient information effectively.

**3.2.6. LCD Screen Displaying NPK Values:**

The LCD screen serves as a visual interface for displaying real-time NPK data collected from the sensor. It provides an immediate and accessible means of monitoring nutrient levels directly on-site. Users can observe the current status of nitrogen, phosphorus, and potassium in the soil, facilitating informed decision-making regarding nutrient supplementation.

**3.3 Pest Detection Tools**

**3.3.1. Camera Module**

The camera module (for experimentation, mobile camera) plays a crucial role in capturing images of tomato plants at scheduled intervals, providing visual data for pest and disease analysis. It is typically configured to capture high-resolution images suitable for machine learning model input.

**3.3.2. Pre-Trained Machine Learning Model (InceptionV3 CNN)**

The heart of the pest detection system, the InceptionV3 Convolutional Neural Network (CNN) model, processes the captured images to identify common tomato plant diseases and pests. Trained on a dataset encompassing diseases like Bacterial Spot, Early Blight, Late Blight, Leaf Mold, Septoria Leaf Spot, Spider Mites, Two-Spotted Spider Mite, Target Spot, Tomato Yellow Leaf Curl Virus, Tomato Mosaic Virus, and healthy plants, the model delivers accurate disease predictions.

**3.3.3 MacroDroid App**

For experimental data collection, the MacroDroid app automates image capture using a mobile camera at specified intervals. Captured images are then automatically synchronized with Google Drive, ensuring seamless data transfer and accessibility for further analysis.

**3.3.4. Watchdog Python Library**

The Watchdog Python library monitors the designated Google Drive folder for new image additions. Upon detection of a new image, the system triggers the machine learning code for disease analysis, initiating the prediction process for timely intervention.

**3.3.5. Twilio Library for Notifications**

Once the machine learning model identifies a disease or pest in the tomato plant images, the Twilio library sends notifications to users, alerting them about the detected issues. This real-time notification system enables prompt action and disease management strategies.

**CHAPTER 4**

**PROBLEM DEFINATION**

**4.1 Problem Statement**

The agricultural sector faces multifaceted challenges ranging from inefficient water management and suboptimal soil nutrient levels to pest and disease outbreaks. Traditional irrigation practices struggle with precision, leading to overwatering or underwatering scenarios that waste water resources and compromise plant health. Manual monitoring of soil moisture exacerbates these challenges, as it often fails to provide real-time insights into plant hydration needs. Concurrently, imbalances or deficiencies in essential nutrients like nitrogen, phosphorus, and potassium hinder plant growth and development, affecting crop yields and quality. Inconsistencies in nutrient management methods further compound these issues, highlighting the need for more precise and automated nutrient monitoring systems.

Additionally, pest and disease outbreaks pose significant threats to agricultural productivity. Conventional detection methods rely heavily on visual inspections, which can be time-consuming and may miss early signs of infestation or infection. Delayed responses to pest and disease issues can lead to substantial crop losses and increased reliance on chemical interventions, with potential environmental and economic repercussions. Addressing these interconnected challenges requires innovative solutions that integrate advanced technologies for accurate soil moisture monitoring, precise nutrient management, and early pest and disease detection. By leveraging data-driven insights and automation, farmers can optimize resource usage, improve crop resilience, and contribute to sustainable agricultural practices.

**4.2 Relevance of the Problem**

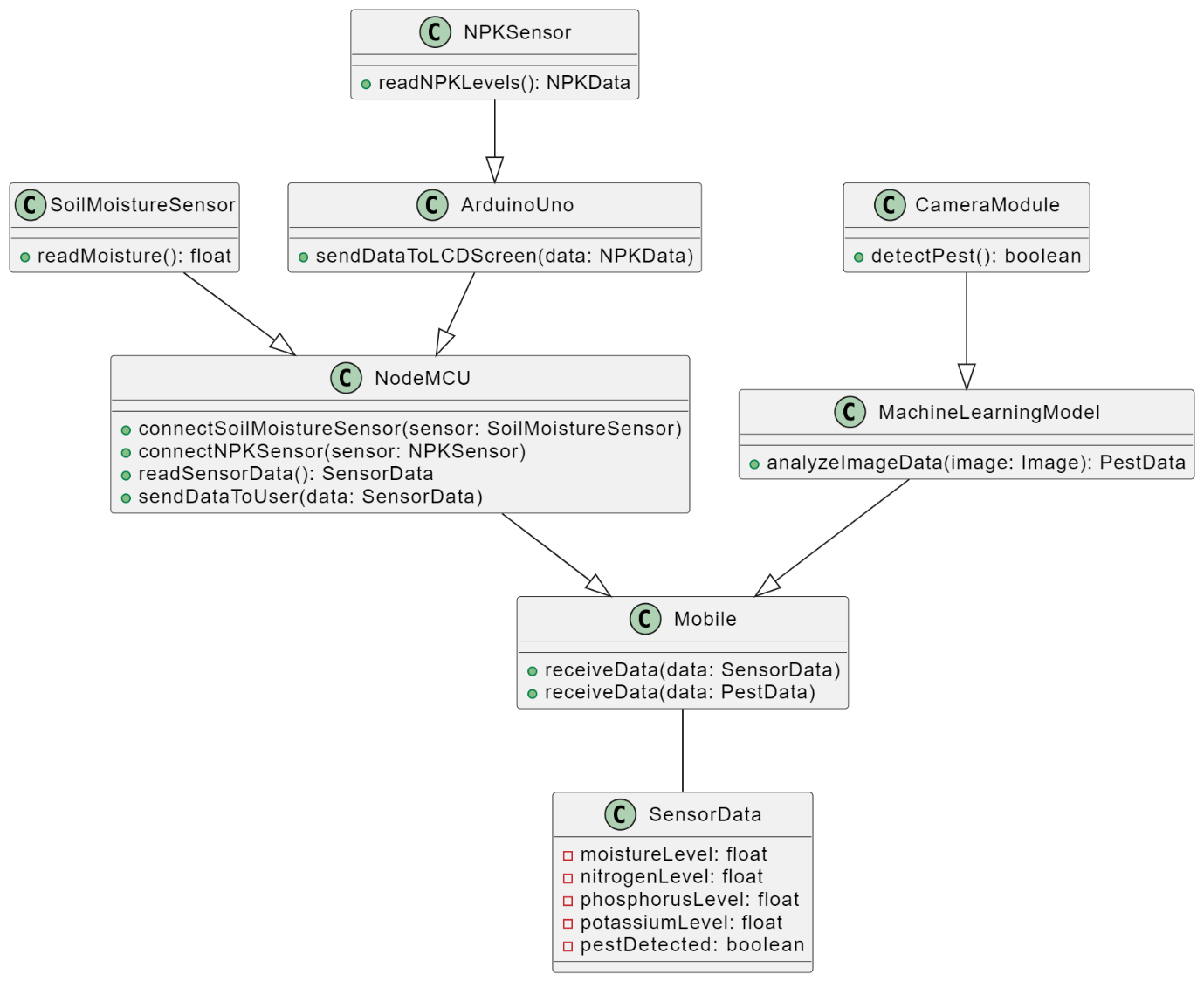
Addressing the challenges in water management, soil nutrient monitoring, and pest detection is crucial for the sustainability and resilience of agricultural systems. Water scarcity and inefficient water usage are pressing concerns globally, especially in regions with limited water resources. Precision irrigation technologies powered by IoT can play a significant role in conserving water, reducing water wastage, and improving overall water efficiency in agriculture. This not only benefits farmers by optimizing resource usage but also contributes to environmental sustainability by minimizing soil erosion, water runoff, and pollution.

Optimizing soil nutrient management is essential for maximizing crop yields, ensuring food security, and promoting sustainable agricultural practices. Imbalances or deficiencies in nutrients like nitrogen, phosphorus, and potassium can lead to decreased crop productivity, poor plant health, and increased vulnerability to pests and diseases. By implementing automated nutrient monitoring systems using IoT devices and smart sensors, farmers can accurately assess soil nutrient levels, adjust nutrient applications as needed, and enhance crop nutrition for optimal growth and yield.

Furthermore, effective pest and disease detection are critical for mitigating crop losses, reducing pesticide use, and promoting ecosystem health. Traditional pest management methods often rely heavily on chemical pesticides, which can have adverse effects on the environment, human health, and non-target organisms. Leveraging advanced technologies such as machine learning models and image processing algorithms for pest detection enables early identification of pest threats, targeted pest control strategies, and integrated pest management (IPM) approaches. This holistic approach to pest management aligns with sustainable agriculture principles, emphasizing environmentally friendly practices, biodiversity conservation, and reduced ecological impact, while ensuring crop health and productivity.

**CHAPTER 5**

**SYSTEM ARCHITECTURE**

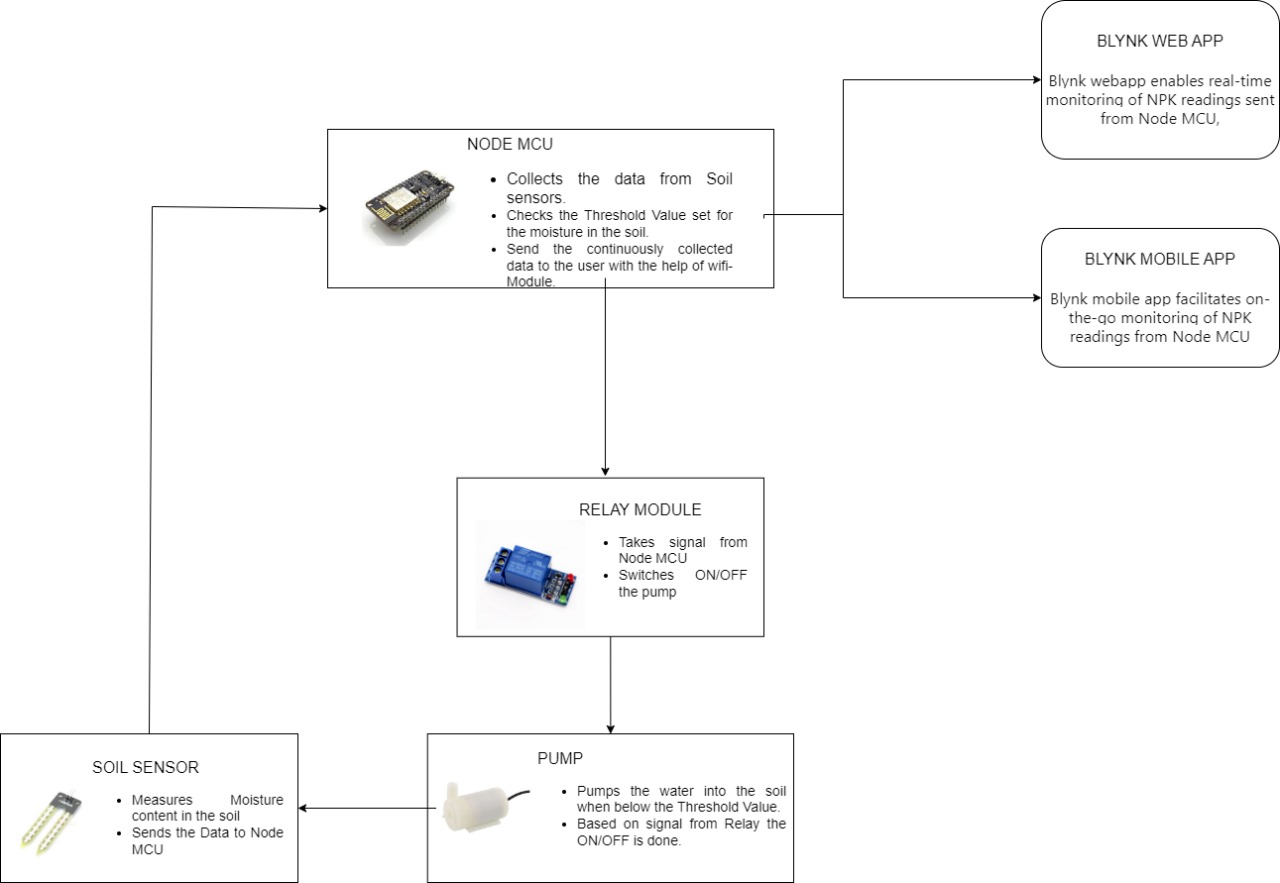
 **Fig 5.1: System architecture**

The smart agriculture system comprises various components interconnected to facilitate efficient monitoring and management of crop conditions. The Soil Moisture Sensor functions as a critical element, measuring soil moisture levels and transmitting this data directly to the NodeMCU. Similarly, the NPK Sensor plays a pivotal role in assessing nitrogen, phosphorus, and potassium levels in the soil, with its data routed directly to the Arduino Uno and the NodeMCU for processing and display on an LCD screen.

The Camera Module is a central component responsible for capturing images of crops for pest detection. It bypasses the NodeMCU and sends these images directly to a pre-trained machine learning model based on InceptionV3 CNN architecture. This model analyzes the images to detect various diseases such as Bacterial Spot, Early Blight, Late Blight, Leaf Mold, Septoria Leaf Spot, Spider Mites, Two-Spotted Spider Mite, Target Spot, Tomato Yellow Leaf Curl Virus, and Tomato Mosaic Virus, as well as healthy plants. Once a disease is identified, notifications are sent to users via the Twilio library, alerting them to take necessary action.

The NodeMCU serves as the central hub connecting the sensors and managing data flow. It collects processed data from the Arduino Uno, including moisture and nutrient levels, and integrates this information with pest detection results from the machine learning model. The NodeMCU then transmits this comprehensive data set to the Blynk mobile application and the pest data is notified to the user via a SMS, offering real-time monitoring and control functionalities to users.

Overall, this system architecture optimizes crop management by seamlessly integrating sensor data collection, machine learning-based pest detection, and user-friendly mobile application interfaces, enabling precise and timely decision-making in agricultural practices. **CHAPTER 7**

**IMPLEMENTATION**

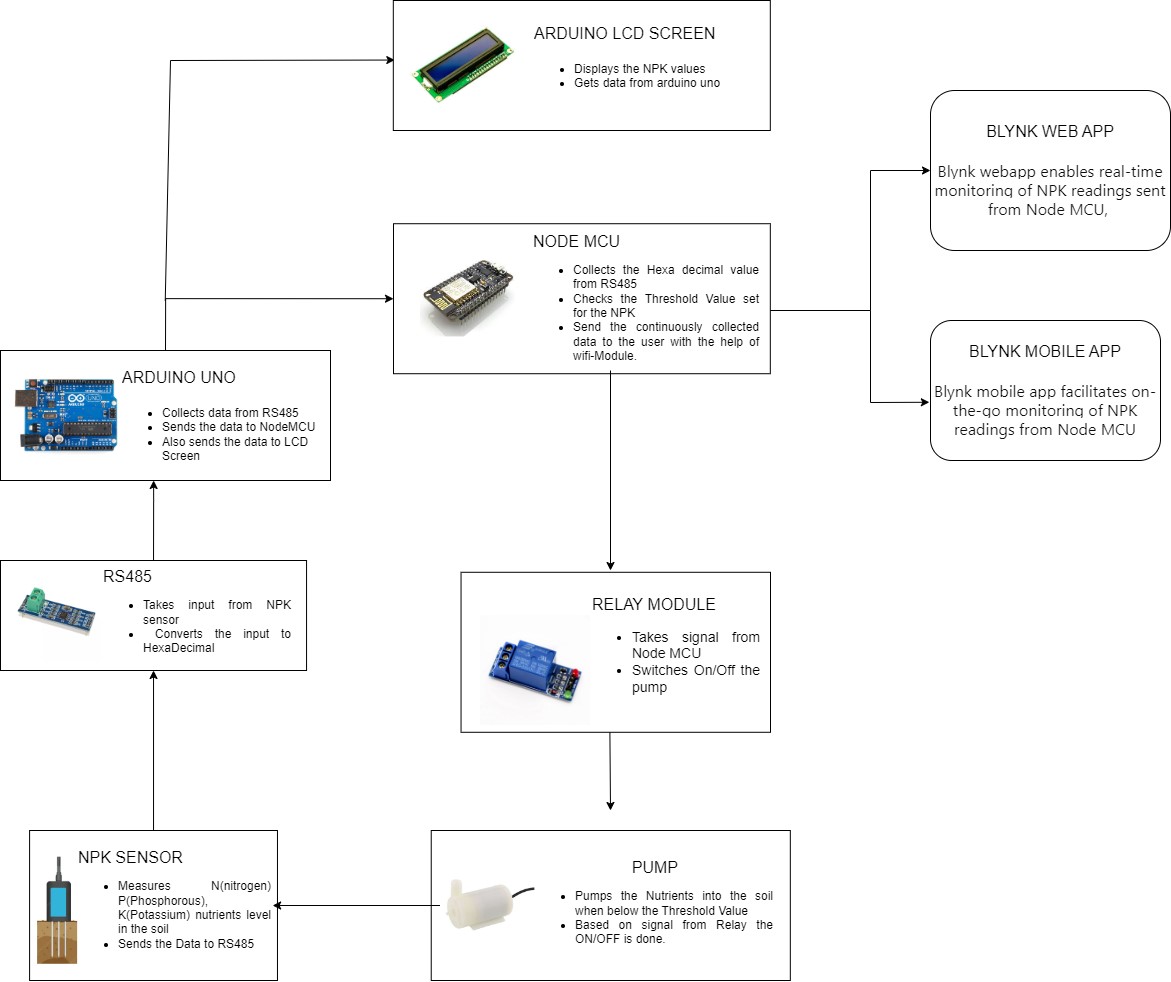
**Fig 7.1: soil moisture monitoring and pumping**

The AB054 Soil Moisture Sensor, is a capacitive type sensor connected to analog pin A0. It measures soil moisture levels, crucial for determining the hydration status of the soil. The sensor's readings are processed in the readSoil() function, where analog data from the sensor is mapped to a moisture percentage value ranging from 0% to 100%. This information is vital as it reflects the soil's ability to retain moisture, influencing plant growth and health.

The NodeMCU acts as the central control unit. It communicates with the soil moisture sensor to retrieve moisture level data, which is then sent to the Blynk app for real-time monitoring. The Blynk app displays the current soil moisture percentage on virtual pin V0, allowing users to track moisture levels remotely.

Additionally, the integrated water pump, controlled by digital pin D1, to regulate soil moisture. When the moisture level falls below 20%, indicating dry soil conditions, the NodeMCU triggers the water pump to irrigate the soil. Conversely, if the moisture level exceeds 80%, suggesting excessive moisture, the pump is turned off to prevent over-watering. This automated pumping mechanism ensures that tomato plants receive adequate hydration, promoting healthy growth and development.

Moreover, the integration of the Blynk app adds a layer of user-friendly accessibility and control. Through the app, users can remotely monitor the moisture level of the soil and the operational status of the water pump. This real-time monitoring capability empowers users with actionable insights, allowing them to make informed decisions promptly. For example, if the app indicates a deviation from the desired soil moisture range or pump malfunction, users can take immediate corrective actions, such as adjusting irrigation schedules or addressing pump issues.



**Fig 7.2: Soil nutrients monitoring and pumping**

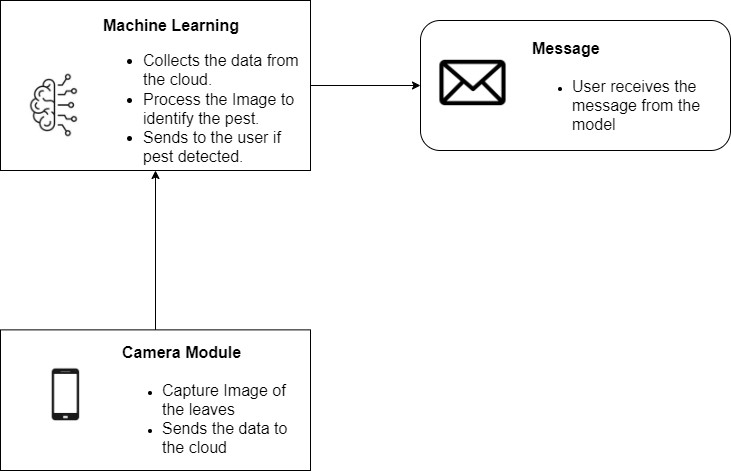
The implementation of soil nutrients monitoring and pumping is a critical aspect of ensuring optimal growth conditions for tomato plants in the smart agriculture system. The system utilizes an NPK (Nitrogen, Phosphorus, Potassium) sensor to collect data on these essential nutrients' levels in the soil. The NPK sensor communicates with an Arduino Uno microcontroller through an RS485 module, which converts the collected data into hexadecimal format for processing.

Upon receiving the nutrient data, the Arduino Uno transmits it to both the NodeMCU and an LCD screen for display. The NodeMCU, serving as the central processing unit, further analyzes the NPK data and sends it to the user via the Blynk app. In the app, users can visualize the percentage of Nitrogen, Phosphorus, and Potassium in the soil, providing insights into the soil's nutrient composition.

The system also incorporates different NPK ratios tailored to various growth phases of tomato plants. For instance, during the vegetative growth phase (0-6 weeks), the recommended NPK ratio might be 20% Nitrogen, 10% Phosphorus, and 10% Potassium. In contrast, during fruit development (6-8 weeks), a ratio of 10% Nitrogen, 20% Phosphorus, and 20% Potassium could be more suitable. Similarly, during ripening (8-10 weeks), a ratio of 5% Nitrogen, 10% Phosphorus, and 15% Potassium might be recommended. These customized NPK ratios cater to the specific nutrient requirements of tomato plants at different stages of their growth cycle, optimizing their health and productivity.

The system integrates an automated pumping mechanism that responds to soil nutrient levels in addition to soil moisture. When the NPK (Nitrogen, Phosphorus, Potassium) levels deviate from the predefined optimal ranges crucial for tomato plant growth, the NodeMCU initiates the pump to maintain adequate nutrient availability in the soil. This dynamic process plays a vital role in sustaining optimal soil nutrient levels, facilitating improved nutrient uptake by the plants and enhancing overall plant health and productivity.

The integration of the Blynk app adds a layer of accessibility and control for users, allowing them to remotely monitor both soil nutrient levels and the status of the water pump. Real-time data visualization and notifications enable proactive decision-making, such as adjusting nutrient supplementation or irrigation schedules, to optimize tomato plant cultivation outcomes. Overall, the soil nutrients monitoring and pumping system forms a vital component of the smart agriculture framework, promoting efficient nutrient management and healthy crop development.



**Fig 7.3: Pest Detection.**

The Automated Tomato Plant Disease Detection System leverages the MacroDroid app to streamline the process of capturing images at specific intervals, adding a layer of automation to data collection. MacroDroid is configured to trigger the camera module at scheduled times, ensuring a consistent and timely acquisition of images depicting the tomato plants' health status. This automation reduces manual intervention, enhances data consistency, and enables a continuous monitoring approach crucial for early disease detection.

Once captured, these images are automatically saved to a dedicated folder within Google Drive, such as the "G:/My Drive/Major-project" folder. Google Drive's synchronization capabilities ensure that these images are seamlessly replicated across devices, including the user's laptop. This synchronization mechanism is vital as it facilitates access to the latest image data for subsequent analysis and processing.

Upon detecting a new image in the synchronized Google Drive folder, the system's machine learning code is triggered to commence the disease detection process. This code, developed using TensorFlow and employing an InceptionV3-based Convolutional Neural Network (CNN) model, undergoes a series of sophisticated computations to extract meaningful features from the images. These features are then analyzed to identify potential diseases affecting the tomato plants or to confirm their healthy state accurately.

Once the disease detection or health assessment is completed, the system generates customized notification messages using Twilio's SMS functionality. These messages are tailored to provide real-time updates on the plant's health status, including any detected diseases, to designated recipient phone numbers. This real-time communication ensures that users stay informed about critical developments in their tomato cultivation, empowering them to take prompt and informed actions to mitigate disease risks and optimize crop health.

In essence, the integration of MacroDroid for automated image capture, Google Drive for seamless data syncing, advanced machine learning algorithms for disease detection, and Twilio for instant communication forms a robust and efficient workflow within the Automated Tomato Plant Disease Detection System. This integrated approach not only reduces manual effort but also enhances the system's accuracy, speed, and effectiveness in addressing disease challenges faced by tomato growers.

The Automated Tomato Plant Disease Detection System is equipped to identify a range of diseases commonly affecting tomato plants. These diseases include:

1. Bacterial Spot
2. Early Blight
3. Late Blight
4. Leaf Mold
5. Septoria Leaf Spot
6. Spider Mites
7. Target Spot
8. Tomato Yellow Leaf Curl Virus
9. Tomato Mosaic Virus

Additionally, the system can accurately classify plants as "Healthy" when no disease symptoms are detected. This comprehensive disease detection capability covers a diverse set of common ailments that can impact tomato plant health and crop yield. By detecting and notifying users about these diseases promptly, the system empowers farmers and agricultural enthusiasts to implement targeted interventions and management strategies, thereby optimizing plant health and overall productivity.