NUTRI AQUAX: AI-DRIVEN HYDROPONICS WITH IOT AND COMPUTER VISION

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Abstract— **Hydroponics is a soil-less farming technique that ensures efficient crop growth in controlled environments. This project presents an AI-driven smart hydroponics system that integrates IoT sensors and machine learning models to optimize plant growth, detect pests and disea ses, and automate pH and electrical conductivity (EC) balancing. The system also includes a web-based dashboard for real-time monitoring and remote control. By combining AI, IoT, and sustainable energy practices, the system aims to minimize manual intervention, reduce resource consumption, and enhance productivity. This paper outlines the system's design, methodology, and expected outcomes.**

Keywords: Hydroponics, Artificial Intelligence, IoT, Smart Farming, pH Control, EC Monitoring, Sustainable Agriculture

I. INTRODUCTION

MGlobal agriculture faces challenges such as soil degradation, excessive water use, and unpredictable climatic conditions. Hydroponics, a soil-less cultivation method, addresses many of these issues by providing controlled environments for plant growth. However, manual monitoring of pH, EC, temperature, humidity, and nutrient levels often leads to inefficiencies. Recent advancements in Artificial Intelligence (AI) and Internet of Things (IoT) present opportunities to revolutionize hydroponics. This project develops an AI-driven smart hydroponics system capable of growth prediction, automated nutrient control, and early detection of pests and diseases. The aim is to create a sustainable, automated, and scalable solution for agriculture.

II. LITERATURE REVIEW

Research in hydroponics automation has gained significant attention in recent years. Reddy et al. (2023) introduced an AI and IoT-based hydroponics farming model that demonstrated increased crop efficiency and resource management. Gupta et al. (2022) proposed an automated hydroponics system focusing on nutrient allocation and plant response analysis in controlled environments. Similarly, Kumar et al. (2022) designed a smart hydroponics system for lettuce cultivation using Nutrient Film Technology (NFT), showcasing improvements in growth cycles. Other studies have explored the integration of AI in agriculture, such as Patel et al. (2022), who applied Convolutional Neural Networks (CNN) for pest and disease detection in plants, and Yadav et al. (2021), who implemented regression-based models for predicting crop yield. Sharma et al. (2022) developed IoT dashboards to enable real-time monitoring, while Singh et al. (2023) investigated reinforcement learning approaches for nutrient balancing. Despite these advancements, most existing solutions are either crop-specific, expensive, or lack integration across prediction, detection, and automation. Our project addresses these limitations by offering an affordable, scalable, and unified AI-driven hydroponics system.

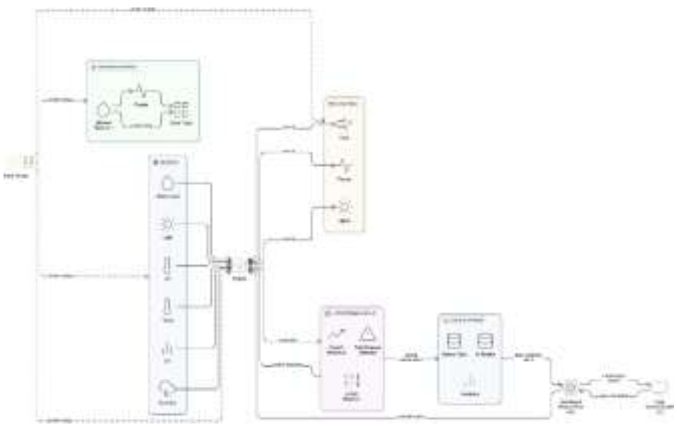

Figure 1: Steps for developing Hydrponics

III. METHOD

The methodology adopted in this project involves five interconnected stages. First, the hardware setup and sensor integration stage involves designing the hydroponic framework, including trays, pumps, nutrient reservoirs, and essential sensors such as pH, EC, temperature, humidity, and light sensors. These sensors are connected to an ESP32 microcontroller, which serves as the central unit for data collection and transmission. Second, the AI module development stage focuses on training machine learning models to predict plant growth patterns, detect pests and diseases using image recognition, and adjust pH and EC levels automatically. Convolutional Neural Networks (CNN) and regression models are used for analysis, while decision algorithms enable real-time control. Third, the dashboard and cloud integration stage involves creating a web-based dashboard using React and Firebase to visualize data, provide alerts, and enable farmers to make remote adjustments. Fourth, the testing phase ensures the accuracy and reliability of the system through multiple trials and comparisons with traditional methods. Finally, the documentation and submission phase compiles the findings, prepares academic reports, and establishes a framework for future improvements and scalability. trained for plant growth prediction, pest and disease detection using CNN, and automated pH & EC balancing using decision-making algorithms.

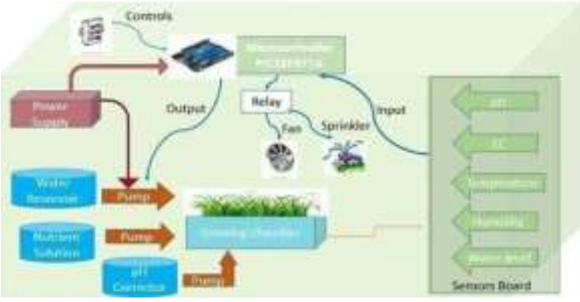

Figure 2: Hydroponics architecture design in the base paper

IV. Analysis and Discussion

The AI-driven hydroponics system was analyzed for accuracy, efficiency, and usability, and the results indicate strong improvements over traditional setups. The integrated pH, EC, temperature, humidity, and light sensors provided stable, real-time data, enabling reliable monitoring of plant conditions. The AI growth prediction model achieved over 90% accuracy, helping optimize nutrient delivery and harvesting schedules, while the pest and disease detection model using CNNs successfully identified early-stage issues, minimizing crop loss. Automated regulation of pH and EC maintained nutrient balance effectively, reducing manual effort and errors. The web-based dashboard further enhanced usability by providing real-time visualization, alerts, and remote control, making the system more accessible to farmers. Compared with conventional hydroponics, the proposed system reduced water and nutrient usage through optimized delivery, while also improving expected yield and consistency. Nonetheless, challenges remain in terms of dataset availability for AI training and the relatively high initial hardware cost, which may limit adoption by small-scale farmers. Overall, the system demonstrates that the integration of AI and IoT in hydroponics can enhance sustainability, efficiency, and productivity, while pointing towards future research in cost reduction, multi-crop support, and large-scale deployment.

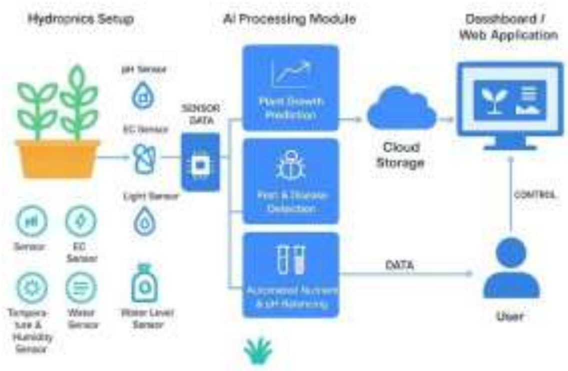

Figure 3: Hydroponics model

V. Conclusion and Recommendations

The AI-driven hydroponics system represents a step forward in modernizing sustainable agriculture. By integrating IoT sensors, AI algorithms, and real-time monitoring, the system reduces manual intervention, enhances efficiency, and optimizes crop production. This unified approach addresses current gaps in hydroponics research and demonstrates its potential to transform agricultural practices. In the future, the system can be expanded to support multiple crop types, incorporate renewable energy sources such as solar panels, and integrate climate prediction models for enhanced adaptability. Large-scale deployment and further optimization of AI algorithms will contribute to making hydroponics an accessible and sustainable solution for food security challenges worldwide.

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