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Arduino-Driven Prototype Nft Hydroponic Automation Utilizing Hybrid Nutrient Calibration Through Tds And Adaptive Water Regulation

[1]Khansa Fatima, [2]Shilpa Shrigiri

[1]Student,[2]Professor

[1]Digital Communication and Networking,[2]Electronics and Communication Engineering,

[1]Sharnbasva University, Kalaburagi,Karnataka,India

Abstract:Nutrition Feeding Automation System plays a significant role in enhancing precision agriculture, particularly in hydroponic farming where nutrient concentration directly influences crop yield and quality. This study presents the design and implementation of an Arduino-driven prototype for Nutrient Film Technique (NFT) hydroponics, integrating a TDS sensor for real-time nutrient calibration and a water level sensor for maintaining optimal solution volume. The Arduino Uno R3 serves as the control unit, processing sensor feedback to regulate nutrient and water delivery through servo-actuated valves. When nutrient concentration falls below 800 ppm, the system automatically dispenses fertilizer until the target threshold is achieved, while low water levels trigger automatic refilling. Experimental testing confirmed accurate detection of solution concentration and responsive adjustment of nutrient and water inputs, demonstrating improved consistency compared to manual methods. The proposed system highlights the potential of embedded automation for hydroponic management, reducing human error and ensuring balanced nutrient delivery for sustainable plant growth in controlled environments.

***Index Terms* –** Hydroponics, Nutrient Film Technique (NFT), Arduino Uno, Nutrition Feeding Automation System, TDS Sensor, Water Level Sensor, Servo Motor, Embedded System, Electrical Conductivity, Automated Agriculture.

I. Introduction

The Nutrition Feeding Computerization System has become increasingly important in modern agriculture, particularly in hydroponic farming where precise control of nutrient delivery is critical for optimal plant growth. Hydroponics eliminates the need for soil by supplying plants with water-based nutrient solutions, allowing for cultivation in environments where traditional farming is limited. Among the various hydroponic techniques, the Nutrient Film Technique (NFT) is widely adopted due to its efficient use of water and nutrients. In this system, a thin film of nutrient solution continuously flows over the plant roots, ensuring a steady supply of essential minerals and oxygen. The effectiveness of NFT depends greatly on maintaining the correct concentration of dissolved nutrients, typically measured in parts per million (ppm) or electrical conductivity (EC).Traditional methods of preparing and monitoring nutrient solutions are mostly manual, relying on growers to mix fertilizers and water in specific proportions. However, such approaches are prone to human error, inconsistency, and labor intensiveness. Excessive nutrient concentration may cause toxicity or plasmolysis in plant cells, while insufficient concentration results in slow growth and low yields. These challenges highlight the need for automation in hydroponic systems to ensure precise, consistent, and timely regulation of nutrient delivery.Advancements in microcontrollers, sensors, and automation technologies have enabled the design of low-cost intelligent systems that address these challenges. The Arduino Uno R3 microcontroller, when combined with TDS sensors, water level detectors, and servo-controlled actuators, provides an efficient platform for automating nutrient feeding in hydroponics. By continuously monitoring solution concentration and water levels, the system can automatically dispense nutrients and maintain balanced conditions without manual intervention. This not only enhances crop productivity but also reduces resource wastage and operational effort.The present study focuses on developing an Arduino-based automated NFT hydroponic prototype capable of adaptive nutrient calibration and water regulation. The system aims to demonstrate how embedded automation can ensure sustainable hydroponic farming, minimize errors, and provide reliable growth conditions for plants in controlled agricultural environments.

II. RELATED WORKS

Article [1]TDS Sensor Based Automatic Nutrient Feeding System for Telegram-Assisted NFT Pakcoy Hydroponic System" is authored by A. H. Hendrawan, F. C. Ramadhan, Ritzkal, R. Ritzkal, and D. Setiadi, published in 2024:Describes an Arduino UNO–based system integrating an ultrasonic sensor for water-level detection, a Gravity TDS V1 sensor for measuring nutrient concentration (in ppm), and automated pumps controlled via relays. When TDS falls below 1050 ppm, the system automatically activates nutrient supply; conversely, above 1400 ppm, it halts dosing. Stirring is managed by a DC motor, ensuring homogeneous solution. System connects to the internet via Ethernet Shield and sends updates to a Telegram platform, enabling remote monitoring. Includes display via LCD for real-time status. The design emphasizes two-tier control: nutrient concentration and water-level management, leveraging sensor-actuator loops to maintain thresholds autonomously.

Article [2] "Development of an Automated Feeding System for Hydroponic Plant Nutrition Using Arduino Uno" by **Siti Aisyah et al.** in **2023**:Demonstrates a TDS-enabled automated nutrition delivery system using Arduino Uno. Initial laboratory studies compared growth and yield between automated and manually fed setups. The automated system delivered consistent nutrition, resulting in improved plant growth and higher yields. Calibration and testing revealed precise nutrient dispensing. The system design also covered control logic, sensor integration, and data collection protocols. The study concluded that automation enhances efficiency, consistency, and productivity in hydroponic operations.

Article [3]"Development of an Automation System for Nutrient Film Technique Hydroponic Environment" by **C. Bambang Dwi Kuncoro, Moch Bilal Zaenal Asyikin, and Aurelia Amaris** in **2021**:Explores a comprehensive NFT hydroponic automation system measuring EC, pH, dissolved oxygen, temperature, flow rate, and water level. Uses sensors, microcontrollers, actuators, and data loggers. Field testing confirmed the system reliably manages nutrient solution parameters, promoting healthy plant growth and quality yield within approximately 3.5 weeks. Demonstrates effectiveness across multiple environmental variables.

Article[4]"Nutrient Film Technique-Based Hydroponic Monitoring and Controlling System Using ANFIS" by **Vito Vincentdo and Nico Surantha** in **2023**:Implements an adaptive neuro-fuzzy inference system (ANFIS) for automatic adjustment of pH and nutrient levels in an IoT-enabled NFT system. Compares ANFIS controller accuracy against conventional fuzzy (Sugeno) methods, demonstrating a 67% improvement. System supports remote control via web dashboard, enabling precise and responsive nutrient and pH regulation through pump actuation.

Article [5]"Designing and Creating an Automatic Hydroponic Plant Watering Control System Using a TDS Sensor Based on an ATMEGA328 Microcontroller" by **Feriandanu Hakim, I Wayan Supardi, and Ni Nyoman Ratini** in **2024**:Uses ATmega328 (Arduino Uno) for an automatic hydroponic watering/nutrient system. The developed device achieved a remarkable 99.99% accuracy in TDS-based detection and water delivery. Hardware components, calibration processes, and control logic are described in detail, demonstrating precision and reliability of the design.

Article [6]"NFT Hydroponic Control Using Mamdani Fuzzy Inference System" by **Indra Agustian, Bagus Imam Prayoga, Hendy Santosa, Novalio Daratha, and Ruvita Faurina** in **2022**:Focuses on NFT systems controlled by Mamdani fuzzy inference, with TDS and pH as control parameters. The system normalizes TDS and pH in a single control step; pH normalization takes ~60 seconds and suppresses oscillations. Demonstrates efficient and stable nutrient regulation with minimal control steps.

Article [7]"Hydroponic NFT-Based Nutrient Solution Acidity Control System Using Multiple Linear Regression Method" by **H. Helmy et al.** in **2020**:Applies multiple linear regression to predict and control acidity in nutrient solutions for NFT systems. Incorporates sensor input and regression models to improve nutrient pH stability. The research shows enhanced precision over static threshold control by adjusting nutrient dosing dynamically.

III. Problem Statement

Hydroponic farming, particularly using the Nutrient Film Technique (NFT), demands precise management of nutrient concentrations and water levels to ensure optimal plant growth and yield. Traditional manual methods for preparing and monitoring nutrient solutions are labor-intensive, time-consuming, and prone to human error, leading to inconsistent nutrient delivery. Excessive nutrient concentrations can cause plant toxicity, while insufficient levels result in stunted growth and reduced productivity. Moreover, manual monitoring of water levels often leads to under- or over-filling, further compromising system stability. The lack of real-time feedback and adaptive control in conventional systems makes it difficult to maintain balanced nutrient and water conditions, especially in large-scale or remote operations.

IV. OBJECTIVES

The primary objective of this study is to design and implement an automated Nutrient Film Technique (NFT) hydroponic system that ensures precise and consistent nutrient and water management for sustainable plant growth. Specifically, the study aims to develop an Arduino-based control system that integrates TDS sensors for real-time nutrient concentration monitoring and water level sensors for maintaining optimal solution volume. The system is intended to automatically adjust nutrient dispensing and water refilling based on sensor feedback, minimizing human intervention and reducing the risk of errors associated with manual operations. Additionally, the study seeks to evaluate the effectiveness and responsiveness of the automated system in maintaining target nutrient levels and solution volumes, ensuring uniform plant growth, improving crop yield, and demonstrating how embedded automation can enhance efficiency, reliability, and productivity in controlled hydroponic farming environments.

V. SYSTEM ARCHITECTURE

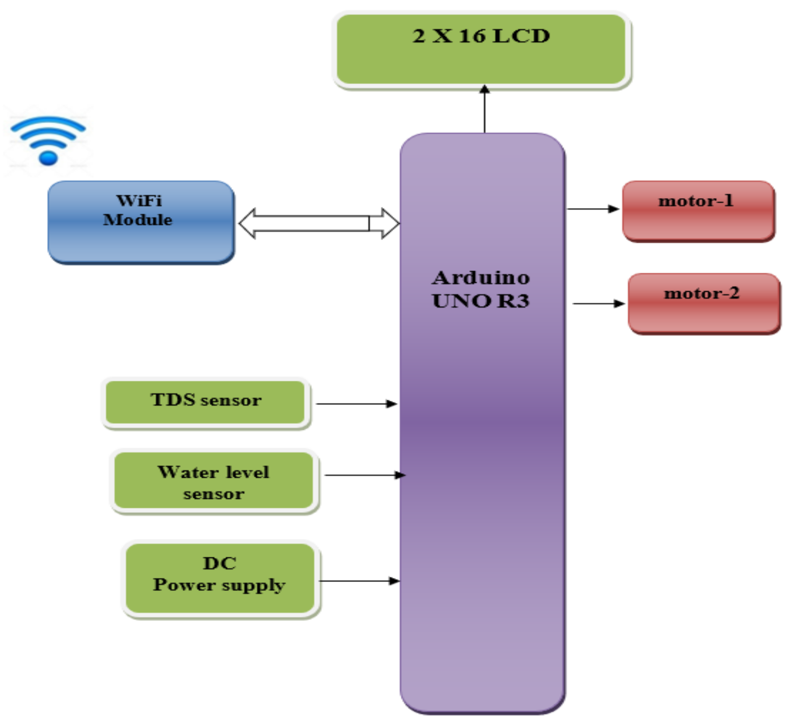

Fig 1:System Architecture

The system architecture depicted in Fig. 1 illustrates an Arduino-based automated hydroponic setup designed for precise nutrient and water management in NFT (Nutrient Film Technique) hydroponics. At the core of the system is the Arduino Uno R3, which functions as the central controller, orchestrating sensor readings, processing data, and triggering actuators. The system integrates multiple sensors to monitor critical parameters: a TDS (Total Dissolved Solids) sensor measures the concentration of nutrients in the solution, ensuring that plants receive an optimal mineral balance, while a water level sensor detects the solution volume in the reservoir, preventing overfilling or depletion. Sensor data are processed by the Arduino in real-time, allowing for adaptive regulation of the hydroponic environment.Actuation is achieved through two motors, labeled as motor-1 and motor-2, which are likely connected to pumps or servo-actuated valves for dispensing nutrients and regulating water flow. The 2×16 LCD module provides a visual interface for displaying real-time system information, such as nutrient concentration, water levels, and operational status, enabling users to monitor conditions directly. Additionally, the inclusion of a Wi-Fi module allows for remote monitoring and potentially remote control of the system, facilitating integration with IoT platforms or mobile notifications. Powering the entire setup is a DC power supply, which ensures stable operation of the Arduino, sensors, and motors. Overall, this architecture demonstrates a closed-loop feedback control system, where continuous monitoring by sensors drives automated adjustments by actuators, promoting consistent nutrient delivery, maintaining water levels, reducing human error, and supporting efficient, sustainable hydroponic plant growth.

VI. EXPERIMENTAL RESULTS

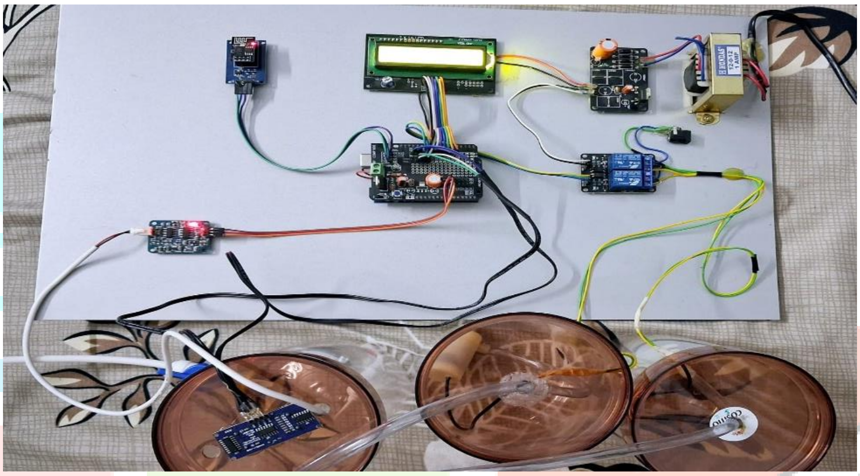

Fig 2:Connection of the Project

Fig 2: Monitoring status TDS & Water Level in Blynk App

VII. CONCLUSION

The Arduino-driven NFT hydroponic automation project successfully demonstrated the development and implementation of a fully automated nutrient and water management system for hydroponic farming. Utilizing the Arduino Uno R3 as the central controller, the system integrated a TDS sensor for real-time monitoring of nutrient concentration and a water level sensor to maintain optimal solution volumes. Actuation was achieved through motor-controlled pumps or servo valves, which automatically adjusted nutrient dispensing and water refilling based on sensor feedback. A 2×16 LCD module provided on-site status updates, while a Wi-Fi module enabled remote monitoring, ensuring that the system could be supervised both locally and via IoT platforms. Experimental testing validated the system's ability to maintain target nutrient levels and solution volumes consistently, outperforming traditional manual methods by reducing human error, labor requirements, and inconsistencies in plant nutrition. The study highlighted the effectiveness of embedded automation in managing hydroponic environments, demonstrating improved growth uniformity and resource efficiency. The tools developed—comprising sensor-actuator loops, automated feedback control, and remote monitoring interfaces—offer practical solutions for controlled agriculture, making hydroponic cultivation more reliable and scalable. Compared to conventional manual operations, the system provides precise, responsive, and sustainable nutrient management, illustrating significant potential for improving crop yield, reducing wastage, and facilitating intelligent agricultural practices. The findings underscore how low-cost microcontroller-based automation can transform hydroponic farming by ensuring accurate, consistent, and efficient management of plant nutrition.

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