Smart Hydroponics, Aquaponics Monitoring and Controlling System for Agriculture Farming Using IOT

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Abstract

Hydroponics is an innovative soil-less method of cultivating plants where nutrients are delivered directly to the plant roots through a water-based solution. Maintaining optimal environmental and nutrient conditions in a hydroponic system is crucial for ensuring healthy plant growth and maximizing yield. Manual monitoring of these parameters such as humidity, light intensity, pH, nutrient levels (NPK), and water availability is labor-intensive, error-prone, and often inefficient.

I. Introduction

Hydroponics is a method of growing plants without soil, where plants are cultivated in a nutrient-rich water solution. This technique has gained popularity due to its ability to maximize crop yield, save water, and enable year-round cultivation, even in areas with poor soil quality. Unlike traditional soil-based agriculture, hydroponics requires precise control of environmental conditions and nutrient levels to ensure optimal plant growth.Manual monitoring and management of hydroponic systems are often **time-consuming and prone to human error**. Parameters such as **humidity, light intensity, pH levels, nutrient concentration (NPK), and water availability** must be maintained within specific ranges. Failure to monitor and regulate these conditions can result in reduced growth, nutrient deficiencies, or even plant death.

II. Literature Review

IoT-based hydroponics and aquaponics systems have gained significant attention in recent years due to their ability to automate and optimize soilless farming. Research shows that integrating sensors such as pH, EC, temperature, dissolved oxygen, and humidity enables continuous monitoring of plant and fish environments. Microcontrollers like Arduino, ESP32, and Raspberry Pi are commonly used to collect data and control pumps, aerators, nutrient dosing, and lighting.Studies highlight that IoT improves system efficiency by maintaining stable nutrient levels, reducing labor, and preventing failures through real-time alerts. Hydroponic systems benefit from automated nutrient control, while aquaponics requires careful monitoring of water quality due to interactions between fish, plants, and bacteria. Machine learning and cloud dashboards are emerging to support predictive control and remote supervision.

III. System Design and Methodology

The proposed hydroponic system uses ESP32 as the central controller to automate the monitoring and control of environmental and nutrient parameters. The system integrates humidity, temperature, light, pH, NPK, and moisture sensors, along with a water pump and relay, to maintain optimal plant growth conditions. Data is uploaded to ThingSpeak for cloud-based visualization and alerts are sent via Telegram for real-time notifications.

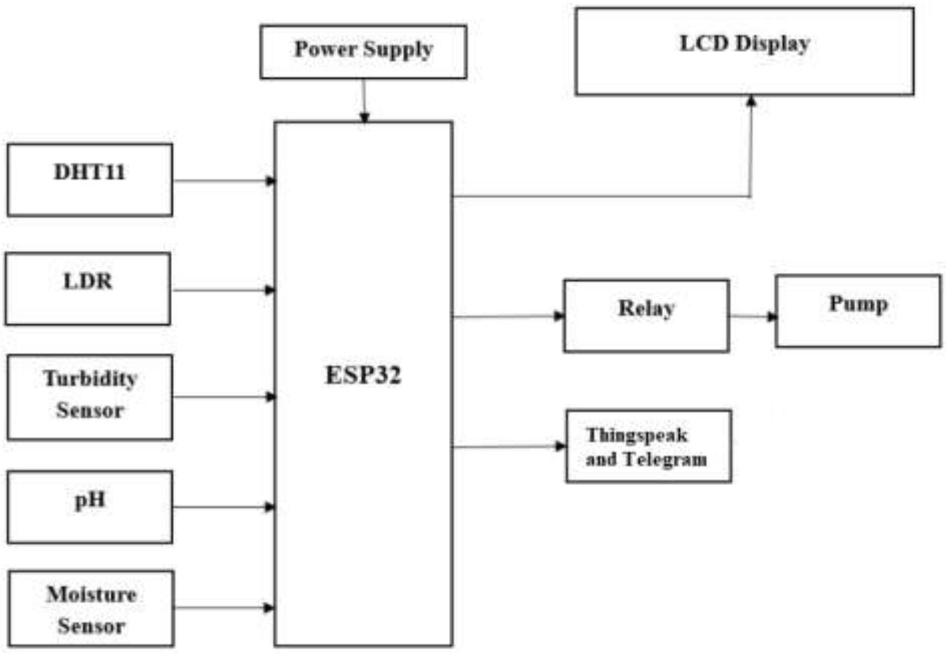

Figure 1: Samrt Hydroponics, Aquaponics Using IOT Block Diagram

IV. Hardware and Software Implementation

- ESP32
- LCD Display
- Soil Moisture Sensor
- Ph Sensor
- Turbidity Sensor
- LDR Sensor
- Relay
- Water pump
- Power Supply

Software Requirements:

- Arduino Ide
- Embedded C

V. Applications

1. Smart Farming Systems: Used in modern farms for automated cultivation without soil.
2. Greenhouse Automation: Monitors temperature, humidity, and nutrient levels in controlled environments.
3. Urban and Vertical Farming: Ideal for cities where space is limited.
4. Research & Education: Helps institutions study plant growth, water quality, and nutrient management.
5. Commercial Hydroponic & Aquaponic Units: Supports large-scale crop and fish production with real-time monitoring.
6. Home Gardening: Small IoT kits can be used by individuals for growing vegetables at home.

VI. Advantages and Limitations

Advantages:
1.Higher Crop Yield: Plants grow faster due to optimized nutrient levels.
2.Water Efficient: Saves up to 90% water compared to soil farming.
3.Less Manual Work: Automation reduces labor and human error.
4.Real-Time Monitoring: Sensors provide continuous updates for better decision-making.
5.No Soil Required: Eliminates soil-borne diseases and pests.
Limitations:
1.High Initial Cost: Sensors, controllers, and setups can be expensive.
2.Requires Technical Knowledge: Users must understand sensors, IoT devices, and nutrient management.
3.Power & Internet Dependency: System may fail during outages if backups are not present.
4.Risk of System Failure: Pump or sensor malfunction can damage plants quickly.

VII. Conclusion

The proposed IoT-based hydroponic system using ESP32 successfully automates the monitoring and control of key environmental and nutrient parameters, ensuring optimal plant growth. By integrating sensors for humidity, temperature, light intensity, pH, NPK, and moisture, the system is able to maintain ideal growing conditions with minimal human intervention.The use of a water pump controlled via relay ensures efficient water and nutrient usage, while real-time data display on the LCD provides on-site monitoring. Remote monitoring and historical data analysis are achieved through ThingSpeak, and critical alerts are communicated via Telegram, enabling timely corrective actions even from a distance.

VII. Future Scope

The hydroponics and aquaponics monitoring and controlling system using IoT has significant potential for future expansion. The system can be integrated with AI-based predictive analytics to optimize nutrient levels, water usage, and plant growth automatically. Machine learning models can forecast plant health issues before they occur, improving crop yield and reducing losses. The project can further evolve with cloud-based dashboards, mobile apps, and real-time alert systems for better remote farm management.

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