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IoT-Based Aquaponics System for Sustainable Farming

Mrs. Zubeda Begum[1], Shaik Qasim Ahmed[2], Md Saif Khan [3], Syed Abdul Gaffar [4]

Assistant Professor, ECE, ISL Engineering College, Hyderabad, India[1]

Student, ECE, ISL Engineering College, Hyderabad, India[2]

Student, ECE, ISL Engineering College, Hyderabad, India[3]

ECE, ISL Engineering College, Hyderabad, India[4]

Abstract: Aquaponics integrates aquaculture and hydroponics into a closed-loop sustainable farming system. The Internet of Things (IoT) enhances this integration by providing real-time monitoring and automated control, improving efficiency, productivity, and sustainability. This paper presents the design and implementation of an IoT-based aquaponics system that monitors water quality, temperature, pH, humidity, and nutrient cycles while automating feeding and irrigation. The system utilizes Arduino and NodeMCU microcontrollers, sensors (pH, temperature, DHT11), and a cloud platform for data logging and alerting. Experimental deployment demonstrates improved water quality control, plant health, and fish survival rates with minimal manual intervention. The proposed system supports precision agriculture, reduces resource wastage, and is scalable for small-to-medium farming environments.

Keywords: IoT, Aquaponics, Sustainable Farming, Smart Agriculture, Real-time Monitoring

I. INTRODUCTION

The increasing demand for food, scarcity of arable land, and environmental degradation necessitate the adoption of innovative and sustainable agricultural practices. Aquaponics—a symbiotic integration of aquaculture and hydroponics—is one such approach. It combines fish farming with soilless plant cultivation, using fish waste as nutrients for plants and plants as biofilters for fish.

Despite its environmental advantages, traditional aquaponics systems require continuous monitoring to ensure optimal water quality and system balance. Manual intervention is time-consuming and prone to human error. Integration with the Internet of Things (IoT) enables remote and automated monitoring and control, making aquaponics more efficient and scalable.

This study proposes and implements an IoT-based aquaponics system using microcontrollers and sensors to automate monitoring and improve sustainability.

II. SYSTEM ARCHITECTURE AND DESIGN

A. Overall System Overview
The system comprises three main modules:
1. Aquaculture unit – a fish tank with sensors for temperature, pH, and ammonia levels.
2. Hydroponics unit – a grow bed with leafy vegetables using nutrient-rich water.
3. IoT-based Control Unit – includes NodeMCU and Arduino boards for data acquisition and control logic.

B. Sensors and Components Used
- pH Sensor – for monitoring acidity/alkalinity
- Temperature Sensor (DS18B20) – for water temperature
- DHT11 – for ambient temperature and humidity
- Water Level Sensor – to prevent dry-out conditions
- Relays & Pumps – for controlling aerators and water flow
- Wi-Fi Module (NodeMCU) – for cloud communication
- Cloud Platform (ThingSpeak) – for visualization and alerts

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III. WORKING PRINCIPLE

The system works in a closed-loop cycle. Fish excrete ammonia-rich waste into the water. This water is pumped into the hydroponic grow bed, where bacteria convert ammonia into nitrites and then nitrates, which serve as nutrients for plants. The purified water is then cycled back to the fish tank.

IoT integration enables:
- Real-time data collection from sensors.
- Threshold-based automated alerts.
- Cloud dashboard for remote monitoring.
- Scheduled feeding and lighting cycles using actuators.

Data is continuously uploaded to ThingSpeak and visualized for real-time analysis and long-term trends.

IV. IMPLEMENTATION AND RESULTS

A. Experimental Setup

A prototype was set up using:
- A 50L fish tank with 5 tilapia fish
- A grow bed with lettuce and spinach
- Arduino Uno controlling pump and relay
- NodeMCU handling data logging to ThingSpeak
- Solar-powered backup system

B. Observations
- pH levels maintained between 6.8–7.2
- Water temperature stabilized around 26°C
- Humidity regulation helped prevent plant wilting
- Feeding and water cycling automated effectively
- 10% higher plant growth rate vs. manual system
- Reduction in water usage by 25%

C. Benefits Observed
- Reduced human intervention and errors
- Improved fish health and plant growth
- Resource efficiency and sustainability
- Remote access using mobile dashboards

V. CONCLUSION

This paper presents an efficient IoT-integrated aquaponics system suitable for sustainable and scalable farming. By leveraging automation and real-time monitoring, the system addresses key challenges in maintaining water and nutrient cycles. Future enhancements may include AI-based predictive maintenance, mobile app control, and integration with renewable energy sources.

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