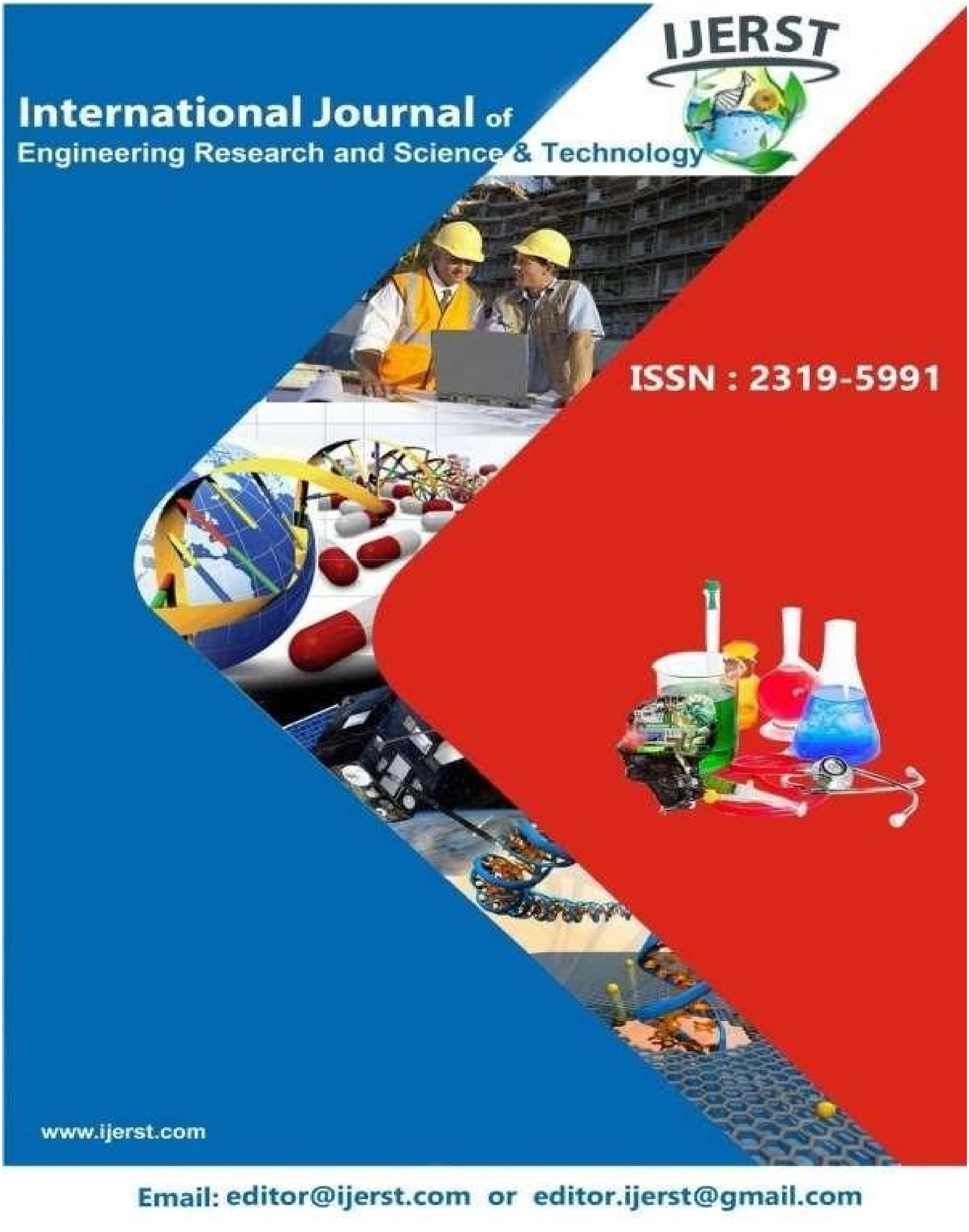

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ESP-32 Based IOT Aquaponics system for sustainable Food management

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Abstract:

Aquaculture is a rapidly growing industry, requiring efficient monitoring and automation to enhance productivity. This project presents an IoT-based real-time fish farming system integrating automatic feeding and water quality tracking. The system employs ESP-32 for wireless connectivity and real-time monitoring. Sensors measure turbidity, temperature, and humidity, ensuring optimal water conditions. An RTC module schedules feeding through an automated feed motor. Inlet and outlet water pumps regulate water flow, maintaining cleanliness. Data is displayed on an LCD and transmitted via Bluetooth and IoT for remote monitoring. The regulated power supply ensures uninterrupted operation. By automating feeding and water quality management, this system reduces manual effort, improves fish health, and increases yield. It provides a sustainable and cost-effective solution for modern aquaculture.Utilizing the ESP-32 microcontroller, the system monitors key water quality parameters such as turbidity, temperature, and humidity, ensuring optimal conditions for fish health. An integrated Real-Time Clock (RTC) schedules feeding times, controlling an automated feed motor that dispenses feed at set intervals, reducing manual labour.To maintain a clean environment, inlet and outlet water pumps regulate water flow and manage waste. Data is displayed on an LCD and transmitted via Bluetooth and IoT platforms for remote monitoring. Powered by a regulated supply, the system ensures uninterrupted operation. By automating feeding and water quality management, this solution enhances fish health and increases yield, promoting sustainability in aquaculture.

Keywords: IoT, ESP-32, real-time monitoring, automation, water quality tracking, automatic feeding, turbidity sensor, temperature sensor, humidity sensor, RTC module, feed motor, water pumps, Bluetooth communication, LCD display, remote monitoring, sustainability, fish yield, regulated power supply.

1. INTRODUCTION

In contemporary world automation plays a vital role. This paper focuses on an automation of Fish farm by using wireless sensor network and mobile communication system. Chicken is the most favorite produce in today's world because it is a nutrient rich food providing high protein, low fat and low cholesterol than other poultries. In this paper environmental parameters of a Fish farm such as temperature, humidity, and ammonia gas are monitored and controlled automatically in order to increase the growth of chicken. Water level also controlled and monitored with the help of sensor module.

By connecting all the sensor modules to the microcontroller all sensor values are acquired then using wifi module it will be uploaded to the web page. This system will control temperature, humidity, ammonia gas and water level with the help of cooling fan, exhaust fan, ventilation window and DC motor without any human interface.Based on the threshold values it will switch on the devices. Thus, this system design provides automated Fish, reduces man power and increases production of healthy chicken. Food availability is a basic need for humans. Cases of poisoning or disease due to consuming contaminated food have occurred in Indonesia, so its availability needs special attention in terms of quality and quantity. The prospect of laying hens in Indonesia is considered very good in domestic and foreign markets when viewed from the supply and demand side. On the supply side, the production capacity of laying hens in Indonesia has not yet reached the actual production capacity.This project introduces an IoT-enabled aquaponics system using the ESP-32 microcontroller to create a sustainable, automated ecosystem for fish growth. Key sensors monitor water quality and environmental conditions, while automated pumps and a feed motor maintain ideal settings.Real-time data is displayed on-site and accessible remotely via IoT, allowing easy adjustments for optimal efficiency. This system demonstrates a scalable, technology-driven solution for sustainable food production.

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2. LITERATURE SURVEY

The system helps to the farmer to monitor the Fish farm and controlling the operations of Fish farm. System is a combination of wireless sensors and mobile system to manage and monitor the Fish's work easier. The environmental parameters like temperature, light intensity and ammonia gas are also monitored and controlled automatically[1]. Internet is linked together to the devices to communicate between thing and the people. The intelligent system can reduce cost, time and labors. The system replaces the human labor to feeding food into container. It overcome the labor problems in the Fish industry and it also involves mainly two sections first to feed the food into particular contained and the second one is to control the temperature sensor to the freshness of chicken's food[2].
It improves Fish's climate and reduce labor cost and save food and chicken feeding on time and avoid contaminated food from insects. The Fish farm uses a computer network technology. In this study, a wireless sensor network technology is designed which monitor and control the climate of Fish farm and also humidity. A computer network technology is useful to the farmers for human work. It

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becomes an automation technology [3]. The automation system improves quality of meat production and then it will impact for the ecosystem balance. The Fish management system uses hardware and open-source software. It also includes temperature, humidity, light intensity and also quality of air. System focusses to provide the setup like IOT, low cost hardware and open source software. System detects many problems faced by Fish industry [4].

It saves time, dependency of labor's and improve healthy environment, also increases Fish production.This system reduce cost, time of labour's ,the system monitor environmental parameters such as temperature, humidity, ammonia gases, water level and maintain a healthy environment. The paper focus on automation of Fish farm using wireless sensor network and mobile communication system. This paper also focuses on environmental parameters like temperature, humidity, ammonia gas these are monitored and controlled fully automatically [6]. By using this automation quality of meat production is improved and growth. The smart Fish farm is fully focus on climate so the quality of chickens will be improved. The climate of Fish farm becomes fully automated. The system's aim is to provide to build an automated environment controlled Fish management system. The system study the physical parameters about Fish house it includes temperature, humidity, moisture content, air and also the quality of the air. System not only monitored the Fish house but also regulates these parameters properly [7].The whole system access and control through remotely using handheld mobile devices. The system reduces labors, saves times. The paper focus to provide the desired climate conditions in Fish house and also to control the performance. The proper method of controlling Fish house the ventilation system is use and it is also include a main factor is air temperature, air humidity [8].The uncertainty of system is also reduced and also this mode contras the system in hierarchical manner this project not only reduce production cost but improved health of animals. The paper focuses to the integration of wireless sensors and GPRS network to control and monitor the environmental parameters in the Fish farm. The environmental parameters like temperature, humidity, ammonia gas etc. System takes immediate action to control these environmental parameters. Food and water level is also controlled and monitor using automated system [9].

Smart helps to the farmers or labor's to monitor and remotely access to the whole system. One of the main benefits is to provide food and water level time to time without wastages. The paper reduces labor's manual work with labor's cost. It improves the meal production in Fish farm. By using wireless sensor data is collected from Fish's environment and it is combined to the sensors. So, controlling and monitoring Fish's climate is easily accessible.

This system provides a monitoring system and which is useful to the owner to receive the information from Fish farm and also to control wirelessly. So this system is able to gather the data and operate automatically and helps to maintain the temperature in Fish farm. Moroccan Fish contributes in the national food security. It focuses on facing obstacles to climate conditions it includes heat in summer and cold waves in winter. The heat losses in the summer in terms of mortality and the cold waves increase the efficiency of the food. i.e. means quality of food is consumed [11]. In this paper to study to saving, cooling and heating in Fish house by using earth-air heat exchanger. The paper includes to improve the Fish farm's production, quality and also economy. Using wireless sensor network, the Fish's growth improves that becomes it is a complete solution for Fish farming. The temperature is also maintained by using this wireless sensor network. By using this system quality and quantity of chickens is improved with human health is also improved [12].

The wireless sensor node would be very useful for early detection of status or health of chickens, and that's why production and economy is achieved. The research paper focuses to development of the wireless sensor node. Wireless system can reduce the public risk and economic cost of the avian-influenza is become to the least. Influenza infection can be detected according to the temperature and monitoring is done at a very early stage [13]. In order to meet the requirements of low power consumption and higher sensitivity, new micro temperature sensor technology was developed. This paper's aim is to determine minimum functions but enough for the practical monitoring. Wireless sensor node and temperature sensor detects infected chickens with the highly pathogenic avian influenza (HPAI) viruses in Fish farms. In early-stage wireless sensor node shows weakness and never of the infected chickens. A global avian influenza surveillance system monitored the health of chickens using wireless sensor nodes with Fish farm [14]. System reports to a user of health conditions obtained by sensors like as fever and weakness. Wireless sensor node has developed to reduce the power consumptionof a device.

3. PROPOSED METHODOLOGY

IoT-enabled aquaponics system leverages the ESP-32 microcontroller to create a sustainable, automated environment for aquaculture. Key sensors, including turbidity, temperature, and humidity sensors, monitor water and environmental conditions essential for fish health. Inlet and outlet water pumps control water flow, while a feed motor automates fish feeding. This system demonstrates an efficient, technology-driven approach to sustainable food management, suitable for both urban and remote farming.

ESP-32 Microcontroller Block The brain of the system, responsible for data processing and controlling the entire fish farming operation. Receives data from sensors, processes it, and sends control signals to actuators. Supports Wi-Fi and Bluetooth connectivity for IoT-based remote monitoring and control. Acts as the central processing unit (CPU) of the system, handling data from sensors and controlling actuators.

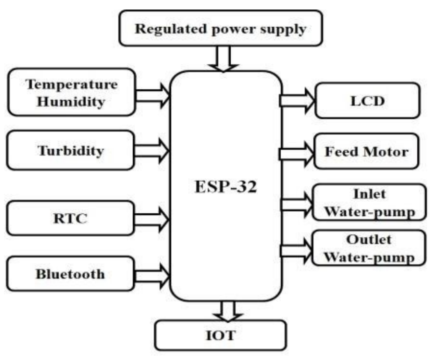

Fig 1: Block Diagram

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The ESP32 has 520 KB of RAM and 448 KB of ROM. It also has multiple memory types, including: SRAM: 520 KB of SRAM, including 320 KB of DRAM and 200 KB of IRAM ROM: 448 KB of ROM for booting and core functions RTC fast SRAM: 8 KB of SRAM for data storage and the main CPU during boot from sleep mode RTC slow SRAM: 8 KB of SRAM for co-processor access during sleep mode eFuse: 1 KiBit (256 bits for the system and 768 bits for other purposes). The ESP32 is a series of low-cost, low- power system-on-chip (SoC) microcontrollers developed by Espressif Systems. These microcontrollers integrate Wi-Fi and dual- mode Bluetooth capabilities, making them ideal for a wide range of Internet of Things (IoT) applications.

Processor: Depending on the variant, ESP32 microcontrollers feature either a single-core or dual-core 32-bit microprocessor. The original ESP32 utilizes the Tensilica Xtensa LX6 microprocessor, operating at clock speeds up to 240 MHz. Some newer variants employ RISC- V single-core processors.Memory: The ESP32 is equipped with 520 KB of SRAM and 448 KB of ROM. Additionally, it includes 16 KB of RTC SRAM for low-power applications.

Bluetooth: Supports Bluetooth v4.2 BR/EDR and BLE, facilitating versatile wireless communication.GPIOs and Peripheral Interfaces: The ESP32 offers up to 34 programmable GPIOs, which can be configured for various functions. Peripheral interfaces include multiple SPI, I²C, I²S, and UART interfaces, as well as PWM and ADC/DAC channels. ESP32 Variants:Since its initial release, several variants of the ESP32 have been introduced, each tailored for specific applications:ESP32-S2: Features a single-core Xtensa LX7 CPU, operates up to 240 MHz, includes 320 KB SRAM, and supports Wi-Fi 2.4 GHz. Notably, it does not support Bluetooth. ESP32-S3: Equipped with a dual-core Xtensa LX7 CPU, operates up to 240 MHz, includes 512 KB SRAM, and supports both Wi-Fi 2.4 GHz and Bluetooth 5 (LE). It also introduces instructions to accelerate machine learning applications. ESP32-C3: Utilizes a single-core 32-bit RISC-V CPU, operates up to 160 MHz, includes 400 KB SRAM, and supports Wi-Fi 2.4 GHz and Bluetooth 5 (LE). It is designed to be pin-compatible with the earlier ESP8266. ESP32- C6: Features a high-performance 32-bit RISC-V CPU, operates up to 160 MHz, includes 512 KB SRAM, and supports Wi-Fi 6 (IEEE 802.11ax) on 2.4 GHz, Bluetooth 5.3 (LE), and IEEE 802.15.4 (Thread and Zigbee). ESP32-H2: Incorporates a single-core 32-bit RISC-V CPU, operates up to 96 MHz, includes 256 KB SRAM, and supports IEEE 802.15.4 (Thread and Zigbee) and Bluetooth 5.3 (LE). This variant does not include Wi-Fi support.

Applications:

This system is a smart, automated, and sustainable solution designed for efficient fish farming. Here are its major applications:

- Automated Feeding System – Ensures fish receive food at scheduled intervals, reducing waste.
- Water Quality Monitoring – Sensors detect turbidity, temperature,and humidity, ensuring a healthy aquatic environment.
- Monitoring & Control – Farmers can access real-time data and control feeding & water pumps from anywhere via IoT.

Advantages:

This IoT-enabled aquaponic system contributes to efficient resource utilization, improved food security, and sustainable agricultural practices, making it an essential tool for modern food management.

- **Smart Agriculture** – Enhances precision farming by automating water quality management, nutrient circulation, and environmental monitoring, ensuring optimal plant and fishgrowth.
- **Urban Farming** – Suitable for small-scale aquaponic setups in urban areas, promoting local and sustainable food production in limited spaces like rooftops and balconies.
- **Commercial Aquaponics** – Used in large-scale farming to monitor and control multiple aquaponic units remotely, reducing labor costs and improving efficiency.
- **Fisheries and Aquaculture** – Helps in monitoring and maintaining ideal conditions for fish health and growth, reducing fish mortality and enhancing productivity.
- **Environmental Conservation Projects** – Supports eco- friendly farming practices by reducing water wastage and minimizing the use of synthetic fertilizers and pesticides

4. EXPERIMENTAL ANALYSIS

The implementation of the ESP-32 based IoT Aquaponics System for Sustainable Food Management successfully demonstrated real-time monitoring and automated control of essential parameters such as temperature, humidity, turbidity, and feeding mechanisms. The system was analyzed based on its functionality, responsiveness, and accuracy of data representation.

1. System Setup and Initialization

- The trainer kit was integrated with essential components, including sensors and an LCD display.

- The system booted up, and the LCD screen displayed "IoT Aquarium System", confirming successful initialization.

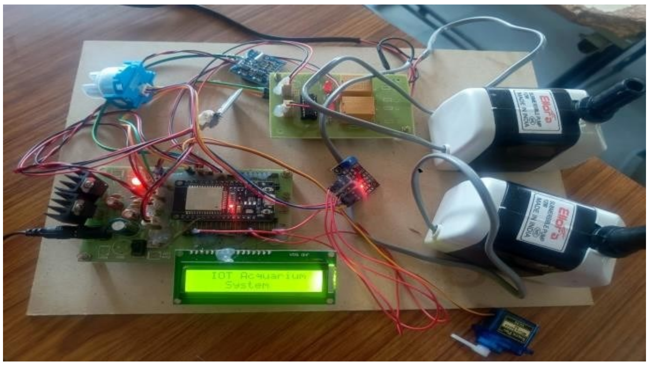

Fig 2:Trainer Kit with Component Integrated

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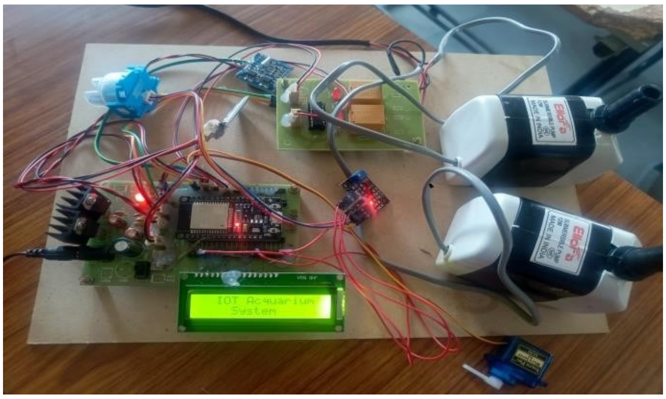

Fig 3: LCD Screen Showing "IoT Aquarium System" Title

2. Real-time Monitoring

- The LCD screen initially displayed "Date and Time", indicating thatthe system was in an idle state, waiting for a network connection.

- Upon successful connection, sensor data related to temperature, humidity, and turbidity were displayed on the LCD, confirming proper sensor integration and data acquisition.

Fig 4:Display Showing "Date and Time"

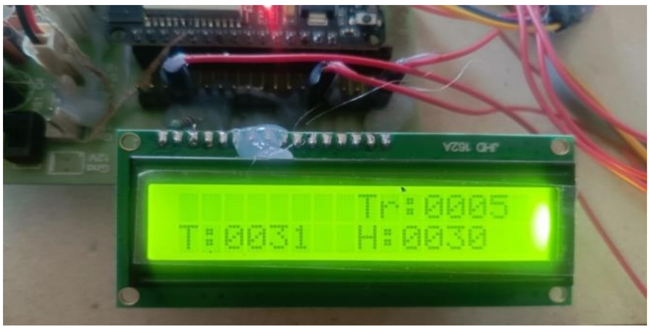

Fig 5: Display Showing "Temperature, Humidity, Turbidity" Values

3. User Control via Mobile Application

- A Bluetooth connection was established using the HC-05 moduleand a mobile application.

- Commands were sent from the mobile application to control various system functions.

Fig 6: Connecting through mobile and giving command to feed function

4. Automated Feeding Mechanism

- A command in the format "@aHH:MM:SS#" was sent to configure the feeding time.

- The LCD confirmed the command by displaying "Feeding Configured".

- At the scheduled time, the system activated feeding, showing

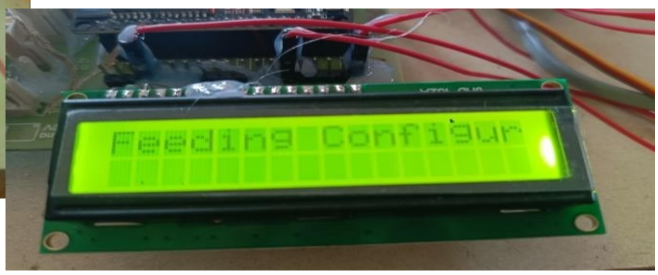

Fig 7: Display Showing "Feeding Configured"

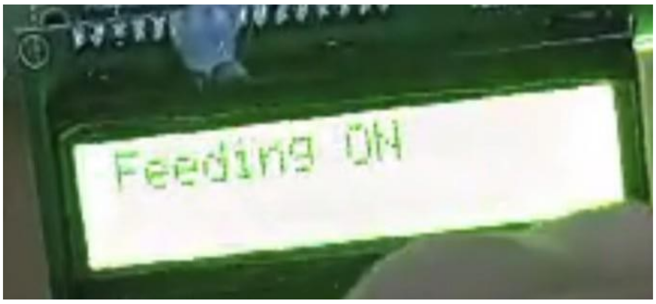

Fig 8: LCD Showing "Feeding ON"

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5. Water Pump Control

- The user sent a command in the format "@dHH:MM:SS#" to control Pump 2.

- The system responded by displaying "Pump2 ON Configured", initiating the water-filling process.

- After the specified duration, the LCD displayed "Pump2 OFF Configured", indicating successful automated control of the water pump.

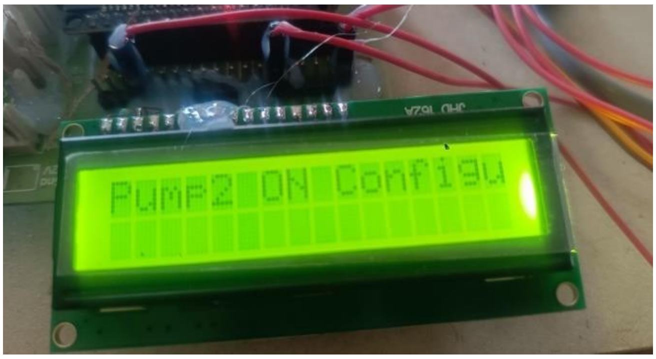

Fig 9: LCD Showing "Pump2 ON Configured"

Successful integration of ESP-32, sensors, LCD, and Bluetooth communication.Real-time monitoring of essential aquaponic parameters.Automated feeding and water control with scheduled execution and confirmation messages.Efficient response to user commands via a mobile application.System reliability in executing functions without manual intervention.

6. System Re-evaluation

- After completing the feeding and water control processes, the system once again measured and displayed the temperature, humidity,and turbidity values to verify any changes in environmental conditions.

Fig 10:LCD Showing "Temperature, Humidity, Turbidity" Values

5. CONCLUSION

The ESP-32 based IoT aquaponic system presents a smart and efficient solution for sustainable food management by integrating modern technology with eco-friendly farming practices. By utilizing IoT-enabled sensors and automated controls, the system ensures optimal water quality, nutrient balance, and environmental conditions for both fish and plants. The real-time monitoring and remote accessibility provided by the ESP-32 enhance productivity, reduce manual intervention, and improve overall system reliability. This innovative approach promotes resource conservation, minimizes water wastage, and reduces dependency on chemical fertilizers, making it an environmentally friendly alternative to traditional farming. Additionally, its application in urban farming, commercial aquaponics, education, and community gardens demonstrates its versatility and potential for widespread adoption. The ESP-32-based IoT Aquaponics System demonstrated efficient real-time monitoring, automated feeding, and water regulation through mobile-based control. The system's performance was validated through LCD-based feedback, ensuring that all commands were executed as intended. Future enhancements can focus on further automation, cloud integration, and AI-driven decision-making for improved sustainability and efficiency.

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