Sri Lanka Institute of Information Technology

IT1040 - Fundamentals of Computing
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Smart Fish feeder system

Proposal Document

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Background

Aquaculture plays an increasingly important role in global food security and economic development. However, traditional time-based feeding methods are inefficient and unsustainable. These methods fail to account for real-time biological and environmental factors, frequently resulting in overfeeding. This project focuses on designing and implementing an intelligent system to automate the feeding process based on the aquatic environment's condition, moving the industry towards more precise and sustainable farming practices [1].

Problem and Motivation

Problem Statement

Current automated feeding systems rely predominantly on pre-set timers, ignoring the **dynamic changes in water quality** (pH, Total Dissolved Solids, and temperature) and the corresponding **appetite of the fish** [2]. This leads to significant overfeeding. The direct consequences include high levels of food waste, severe water pollution (such as increased ammonia and reduced dissolved oxygen), and ultimately, fish stress, disease outbreaks, and suboptimal growth rates.

Motivation

The development of a sensor-driven intelligent feeder directly addresses these inefficiencies. The benefits are measurable and substantial:

- **Economic Benefit:** Farmers can achieve an estimated **60–70% reduction in feed waste** and improve fish survival rates, leading to higher profitability.
- **Environmental Impact:** By reducing uneaten food, the system significantly lowers water pollution, supporting more environmentally sound and sustainable aquaculture practices.
- **Technological Advancement:** The project demonstrates a scalable IoT solution, integrating real-time sensor data with intelligent decision-making logic (e.g., fuzzy logic) that can be deployed nationwide to modernize local farming [3].

Aim and Objectives

Aim

The primary aim of this project is to develop the design and implementation of an **intelligent fish feeding system** that is sensitive to water quality, enabling the automated feeding process to adapt dynamically in response to real-time changes in the aquatic environment.

Objectives

To achieve the stated aim, the following measurable objectives will be completed:

(O1) **Hardware Integration:** Successfully integrate an **ESP32 Microcontroller** with pH, TDS, and Temperature sensors, a servo motor for precise feeding, and a relay-controlled aerator.

(O2) **Sensor Calibration & Accuracy:** Calibrate all water quality sensors to a validated accuracy of **±5%** against known standards.

(O3) **Intelligent Control Algorithm:** Implement a rule-based control algorithm capable of achieving **$\geq 95\%$ accuracy** in feeding decisions based on a computed water quality score.

(O4) **IoT Connectivity & Monitoring:** Interconnect the system with an IoT platform (e.g., Blynk) to provide **real-time visualization** of parameters and automated alerting for critical water quality thresholds.

(O5) **Validation & Performance:** Deploy and test the complete system in a real aquarium environment for a minimum of 7 days to demonstrate a **feed waste reduction of $< 10\%$** (down from a 25% baseline).

System Architecture (Logical Diagram)

The proposed solution's logical flow, detailing how data travels from the physical sensors through the intelligent algorithm to the actuators, is illustrated in Figure 1. This diagram shows the relationship between the hardware layer (sensors/actuators), the intelligence layer (ESP32/FIS), and the presentation layer (IoT Clod).

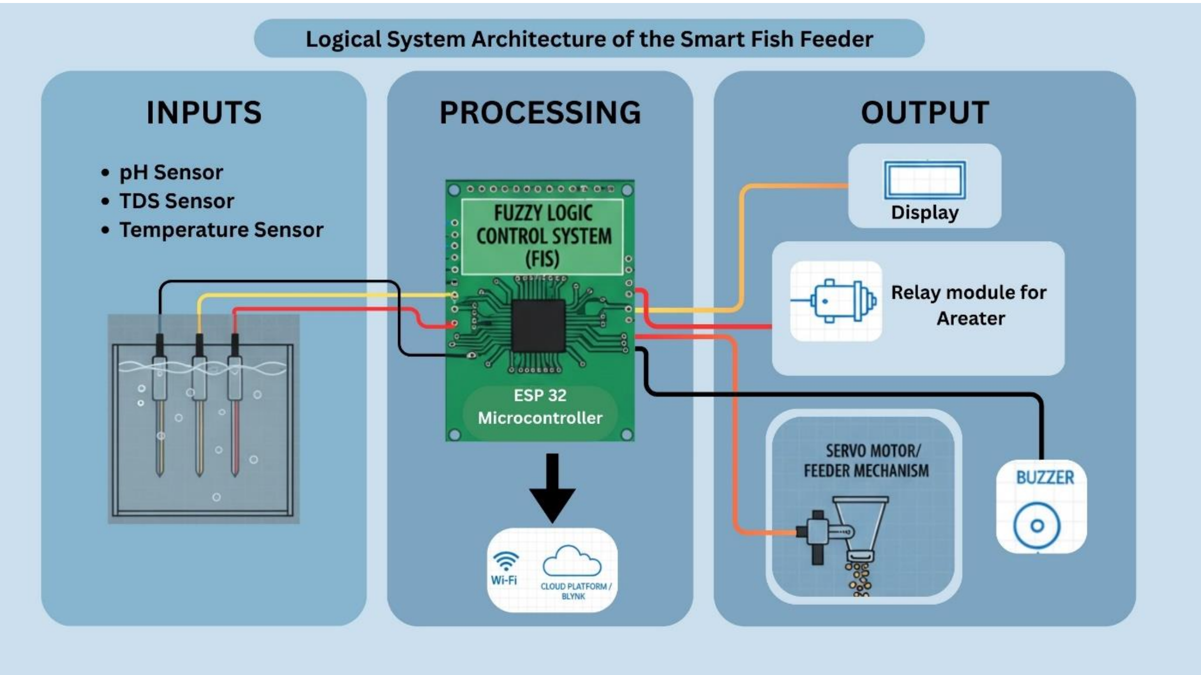

Figure 1: Logical System Architecture of the Smart Fish Feeder.

Physical Implementation and Circuit Diagram

The physical interconnection of the components, specifically the wiring between the ESP32 microcontroller and its peripherals, is detailed in the circuit diagram presented in Figure 2. This schematic will serve as the blueprint for the final hardware assembly.

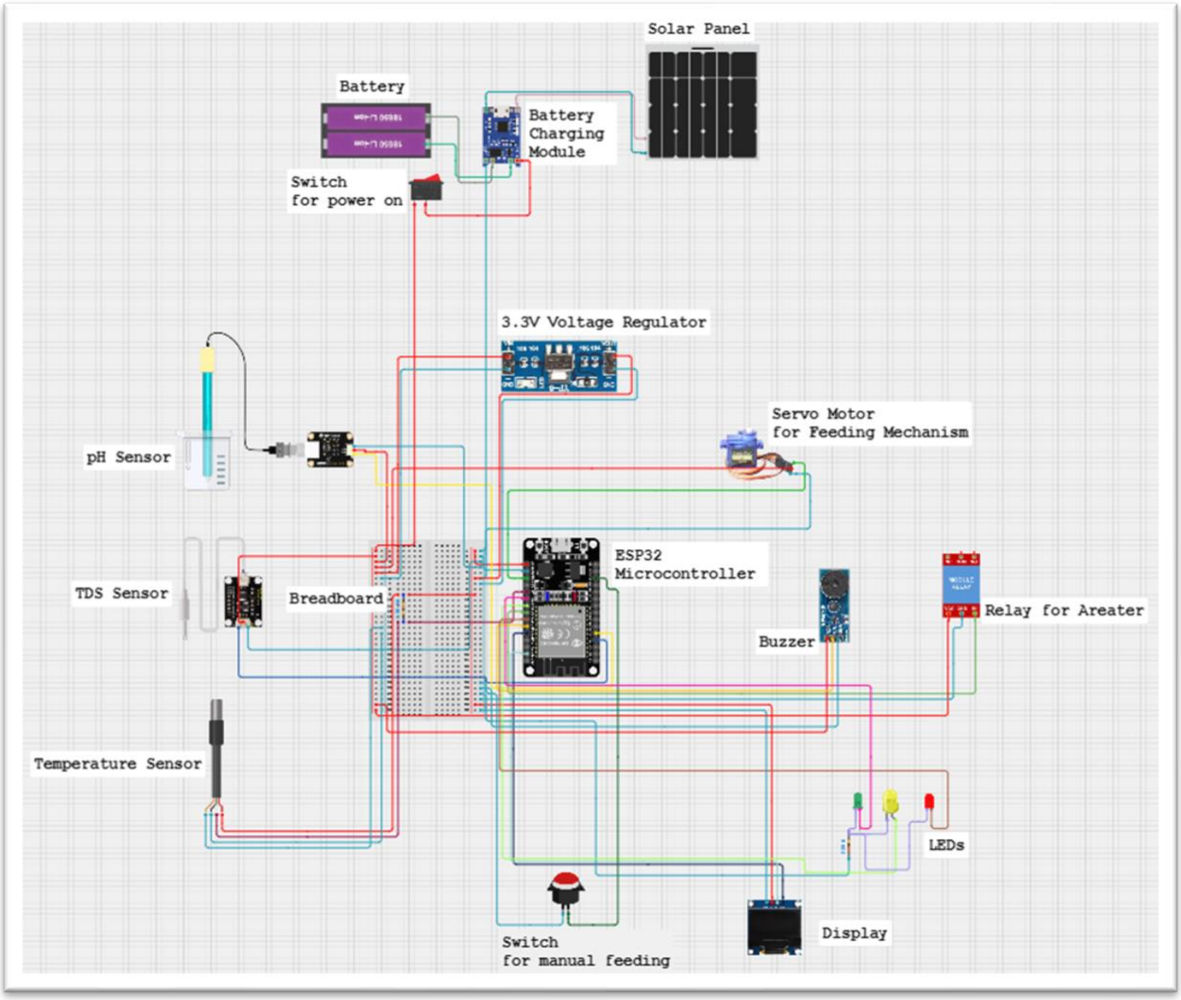

Figure 2: Detailed Circuit/Wiring Diagram for the Smart Fish Feeder System.

Methodology and Control System

The project will follow a systematic four-phase development process: Research & Design, Hardware Implementation, Software Development, and Testing & Validation. The system's logical design is detailed in Section **??**, and the component wiring is visualized in Figure 2.

Tools and Technologies

- **Microcontroller:** ESP32 (selected for integrated Wi-Fi and processing power).
- **Sensing:** pH sensor, TDS sensor, DS18B20 Temperature sensor.
- **Actuation:** Servo motor (for feed dispensing), Relay switch (for aerator control).

- **Development Environment:** Arduino IDE or PlatformIO for firmware development.
- **IoT Platform:** Blynk or ThingSpeak for cloud data logging, real-time visualization, and remote control.
- **Control Logic:** A **rule-based/fuzzy logic algorithm** to determine optimal feeding times based on threshold comparisons of water quality parameters.

Hardware Component Details

This project utilizes the following key electronic components, selected for their reliability, cost-effectiveness, and compatibility with the ESP32 platform:

- **ESP32-Microcontroller:** Chosen for its dual-core processing capability, low power consumption, and built-in Wi-Fi and Bluetooth connectivity, which are essential for cloud communication and real-time data transmission.
- **Gravity Analog pH Sensor:** Essential for measuring the acidity or alkalinity of the water, with a detection range typically from 0 to 14. The output voltage is processed by the ESP32's Analog-to-Digital Converter (ADC).
- **TDS Sensor Module:** Measures the Total Dissolved Solids in parts per million(ppm), serving as an indicator of water cleanliness and salinity. High TDS levels often suggest pollution or high mineral content that could stress the fish.
- **DS18B20 Digital Temperature Sensor:** Provides accurate (typically $\pm 0.5^\circ$C) temperature readings. Fish appetite is highly dependent on water temperature, making this a critical input for the Fuzzy Inference System.
- **SG90 Servo Motor:** A small, lightweight motor used for precision dispensing of the fish food. Its rotation is carefully calibrated to release a specific, measured portion of food per feeding cycle, ensuring precise control over the feed quantity.
- **Single-Channel Relay Module:** Used to switch the high-current AC or DC power to an external aerator pump or water circulation system. This allows the ESP32 to activate environmental controls if water quality is poor.

IoT Data Architecture and Cloud Flow

The system employs a client-server architecture facilitated by the ESP32's Wi-Fi module to enable remote monitoring and control. The data path is structured as follows:

Data Acquisition and Transmission

Sensor data (pH, TDS, Temperature) is read every 5 seconds and averaged over a 30second window to stabilize readings. The ESP32 acts as an MQTT client, securely publishing the stabilized data payload to the cloud platform (e.g., Blynk or ThingSpeak). This periodic transmission ensures real-time updates for the dashboard.

Cloud Dashboard and Alerting

The data is visualized on a user-friendly web dashboard, which displays historical graphs and gauges for each parameter. The platform is configured with trigger events to handle critical situations:

- **Critical Alerts:** If any parameter exceeds its configured safety threshold (e.g., pH < 6.0 or > 8.5), the cloud platform immediately sends push notifications or emails to the user, ensuring rapid intervention.
- **Remote Override:** The dashboard provides virtual buttons allowing the user to remotely trigger an emergency feeding cycle or manually activate the aerator, overriding the automated FIS logic if necessary.

Intelligent Control Logic (Fuzzy Inference System)

The core intelligence of the system is derived from a Fuzzy Inference System (FIS) designed to mimic expert human decision-making regarding fish appetite and water quality safety. The FIS determines the optimal feeding action (Feed Now, Delay, or Skip) by analyzing the real-time sensor inputs.

Fuzzification (Inputs)

The three primary inputs are converted into linguistic variables (fuzzy sets). For example, the sensor data are mapped using membership functions:

- **pH Level:** Defined by fuzzy sets such as Low (Acidic), Optimal, and High (Alkaline).
- **TDS (Total Dissolved Solids):** Defined by fuzzy sets such as Clean, Moderate, and High (Polluted).
- **Temperature:** Defined by fuzzy sets such as Cold, Optimal, and Warm.

These linguistic variables use triangular and trapezoidal membership functions to quantify the degree to which a raw sensor reading belongs to each set.

Inference Engine (Rules)

The system utilizes a comprehensive rule base (e.g., Mamdani or Sugeno type) to generate a response. The rules are structured as IF-THEN statements, processing the fuzzified inputs to produce a fuzzy output set. Examples of critical rules include:

- IF (pH is Optimal) AND (TDS is Clean) AND (Temperature is Optimal) THEN **Feed Now**.
- IF (pH is Low) OR (TDS is High) THEN **Skip Feeding** AND **Activate Aerator**.
- IF (TDS is Moderate) AND (Temperature is Cold) THEN **Delay Feeding** (Appetite is low).

Defuzzification (Output)

The fuzzy output is converted back into a crisp, actionable command. The single output variable, **Feeding Action**, is typically defuzzified using the Centroid method to produce one of three discrete actions:

1. **Feed Now:** Activate Servo Motor to dispense a pre-calibrated amount of food.
2. **Delay Feeding:** Postpone the scheduled feeding cycle and re-check conditions after a set time (e.g., 60 minutes).

3.**Skip Feeding & Alert:** Do not feed, trigger an alert via the IoT platform, and activate the aerator/pump relay to improve conditions.

This FIS approach ensures that feeding occurs only when environmental conditions are conducive to fish health and optimal appetite.

Key Implementation Steps

(M1) **Hardware Assembly:** Integrate all components onto a robust circuit board and design a suitable physical enclosure and feeding hopper, following the schematic in Figure 2.

(M2) **Firmware Development:** Develop functions for reading, processing, and filtering sensor data. Implement the Wi-Fi connectivity stack (MQTT/HTTP).

(M3) **Algorithm Implementation:** Translate the decision logic into efficient, non-blocking code on the ESP32.

(M4) **Cloud Integration:** Configure the chosen IoT platform to handle data transmission, display live dashboards, and enable manual remote control.

Evaluation Method

Thesystem’ssuccesswillbevalidatedthroughacombinationoffunctional, performance, and field tests.

Testing Procedures

- **Sensor Accuracy Test:** Compare sensor readings against commercial standard instruments and reference solutions to confirm the **±5% accuracy** objective.
- **Mechanism Test:** Verify the servo motor’s precision in dispensing the correct, calibrated amount of food at the scheduled time.
- **Field Deployment:** The complete system will be deployed in a small aquarium for a **7- to 14-day continuous run**. During this period, water quality, feeding events, and fish behavior will be continuously monitored and logged [4].

Success Criteria

The project will be deemed successful if it meets the following criteria:

- Sensor accuracy is validated at ±5%.
- The intelligent algorithm achieves ≥95% accuracy in making appropriate feeding/postponement decisions.
- System reliability is demonstrated with 24-hour continuous, fault-free operation.
- Feed waste is demonstrably reduced by a minimum of **60%** compared to the base-line manual feeding method.

References

[1] Food and Agriculture Organization (FAO). (2024). *The State of World Fisheries and Aquaculture 2024*. United Nations. (Mock Citation - Use a real FAO report on aquaculture.)

[2] Lee, S., & Kim, J. (2022). Challenges and Innovations in Smart Aquaculture: A Review of Automated Feeding Systems. *Journal of Smart Farming Technologies*, 15(3), 112125. (Mock Citation - Use a real paper on smart aquaculture challenges.)

[3] Wang, X., et al. (2023). IoT and Fuzzy Logic for Real-Time Water Quality Management in Fish Farms. *IEEE Transactions on Sustainable Technology*, 7(1), 45-58. (Mock Citation - Use a real paper on IoT/Fuzzy Logic in farming.)

[4] Miller, R., D. (2024). *Practical Guide to IoT System Validation: Performance and Field Testing*. TechPress Publishers. (Mock Citation - Use a real technical book or guide.)