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Automated Fish Farm: A Comprehensive Approach to Automated Feeding, Water Quality Monitoring and Biodiversity Conservation

Sagnik Palit, Sourajit Mukherjee, Soumyajit Mondal, Dr. Uttam Chowdhury

Department of Electrical Engineering
Techno Main, Salt Lake, Kolkata – 700091, West Bengal, INDIA

ABSTRACT

Global population growth intensifies pressure on food resources, emphasizing the need for sustainable food production. India, ranking third in global fish production, and being fourth-largest fish exporter, the country possesses over 10% of global fish diversity.

In the fiscal year 2021-2022, 75% of India's fish production originated from inland fisheries, prompting the need for advancements in fish farming. Our project addresses this by establishing a miniature, automated fish farm to enhance safety, efficiency, and reliability, minimizing human intervention.

Aquaculture, involving breeding and harvesting of aquatic organisms, leverages IoT, microprocessors, and automation. Using Arduino UNO and sensors, our project ensures optimal water quality by monitoring parameters like temperature, pH, Total Dissolved Solids (TDS), water color, and electrical conductivity.

Automation includes an innovative feeder system with motors and servo facilities for a healthy feeding cycle, promoting fish growth without human intervention. Automatic pump systems, guided by real-time water turbidity and color detection, foster a conducive environment for aquatic life, saving time, money, and power.

Emphasizing reliable automation, our project employs fully automated sensors, relays, motors, and a fish counting feature for real-time monitoring and control. This approach ensures precision, accessibility, and error-free management of the fish farm, contributing to wildlife conservation, especially for endangered species like Hilsa and Tuna which can later be extended for other wildlife creatures as well in their respective environment.

Keywords: global population growth, sustainable food production, automated fish farm, safety, efficiency, reliability, Arduino UNO, temperature, pH, TDS, water color, electrical conductivity, feeder system, turbidity and color detection, error-free, wildlife conservation

I. INTRODUCTION

Aquaculture, encompassing the breeding, rearing, and harvesting of various aquatic organisms, addresses the escalating demand for seafood in diverse water environments under controlled or semi-controlled conditions. The surge in this demand has outpaced the current supply, necessitating more efficient harvesting methods to meet market needs. Unfortunately, this heightened demand contributes to the decline of specific fish species, particularly those considered delicacies. Moreover, it plays a crucial role in habitat restoration, and replenishing wild stocks. This sustainable approach aims to counterbalance the environmental impacts associated with traditional fishing practices and ensure a controlled and efficient supply of aquatic products to meet global demands.

Aquaculture includes a distinct branch known as fish farming, which focuses on the controlled breeding of fish in specific settings like fish tanks or artificial enclosures such as ponds, mainly for the purpose of food production. This sector within aquaculture involves the controlled growth and harvesting of various aquatic creatures, including fish, crustaceans, and mollusks. Globally, the Food and Agriculture Organization (FAO) estimates that nearly half of seafood consumption is sourced from aquaculture. [1] Asia dominates aquaculture production, contributing 89% of the global total of 73.8 million metric tons, with leading countries including China, India, Indonesia, Vietnam, and Bangladesh.

Composite Fish Culture (CFC), developed in the 1970s by the Indian Council of Agricultural Research, involves cultivating 5 to 6 species of both local and imported fish in a single pond. Careful selection prevents competition for food and space. For instance, combining surface feeders like Catla and Silver Carp with column feeder Rohu and bottom feeder Mrigal reduces the need for external food and minimizes waste. Under optimal conditions, CFC yields 3,000 to 6,000 kg of fish per hectare annually.

Some advantages and disadvantages of Aquaculture are as follows:

Advantages:

1. Replenishment: Fish farming aids in replenishing the food fish supply faster than natural ecosystems.
2. Employment and Profitability: The industry creates jobs, particularly in Asia, offering financial support to communities.

3. Nutritional Provisions: Fish farming contributes to nutrient-rich seafood, combating malnutrition.

Disadvantages:

1. Environmental Damage: Dense fish populations in farms can release concentrated toxic waste, polluting local water sources.
2. Feeding Challenges: The need for fish meal as feed poses inefficiencies and resource imbalances.
3. Disease and Contamination: Fish farms can become breeding grounds for bacteria, sea lice, and diseases, potentially impacting wild ecosystems.

However, challenges like resistance to newer methods persist due to capital and knowledge constraints. Technology advances, including automation, offer potential solutions. Despite current high costs and maintenance requirements, aquaculture is anticipated to be a major seafood source, addressing the inevitable decline in wild fish populations.

Automating fish farming and aquaculture ensures significant gains in productivity and reliability. Integrated systems offer real-time plant monitoring through web platforms on mobile or PC, enhancing the Feed Conversion Ratio (FCR) and promoting rationalization and savings. Automation facilitates rapid, growth-oriented advancements, reducing human involvement in maintenance, and ensuring reliability and uniformity. Continuous, uninterrupted service is achievable through automated processes, with occasional interruptions during maintenance. Automated sensors provide detailed fish analysis, surpassing human observations in reliability. Real-time connections with farm management software, artificial intelligence, and big data enhance operational efficiency. Automated feeders and sensors enable precise food traceability, minimizing contamination risks. Restricting daily access to tanks mitigates contamination risks for sensitive fish, while automated feeders control food distribution, reducing water pollution. Implementation of these technologies promises tremendous productivity and profitability in the aquaculture sector. We will fist explore the various key factors affecting the water bodies along with reasons for eliminating other dependent factors under Section II. We will examine the hardware and software components utilized in our project, detailing their integration and functionality under Section III. We will then present the obtained results and delve into their significance under Section IV. Lastly, we will summarize project outcomes against objectives and discuss potential for large-scale implementation under Section V.

II. LITERATURE REVIEW AND REALIZATION

Several literature papers in the overview focus on the impact of water quality parameters on aquatic life and the use of IoT to address related challenges. IoT applications in agriculture have gained attention [2], particularly in aquatic environments. Numerous papers concentrate on specific sensors like pH, Dissolved Oxygen (DO), and Turbidity [3][4], proposing solutions for these issues. However, optimal fish production depends on various water characteristics like DO, Temperature, Ammonia, Salt, pH, Nitrate, Turbidity, Transparency, Water Color, Carbon Dioxide, Alkalinity, Hardness, Conductivity, Salinity, TDS, Nitrates, Nitrites, Plankton Population and Carbonates [5]. But using so many sensors for measurement of each of these parameters would be very costly as well as tedious. Our project focuses on the making of an automated fish farm using only some of the key parameters whose imbalances can affect other factors as well and thus controlling them would indirectly control all the factors that are necessary for maintenance of water quality that is required for optimal fish production. Hence, we will focus on these key parameters first - temperature, pH, conductivity, and water color. [4][6]

Changes in temperature have significant impacts on biological and chemical processes, influencing fish migration, reproduction, and distribution. A mere 10^{o} increment results in nearly doubling the rate of these reactions [7]. Fish exhibit specific temperature tolerance limits within an optimal range, and even a slight $5^{o}C$ change can induce stress or, in extreme cases, lead to the demise of fish [8]. Additionally, parameters such as pH, dissolved oxygen (DO), conductivity, and salinity are directly influenced by variations in temperature [9]. So, temperature is our first consideration.

The pH level represents the ratio of hydrogen ion concentration, indicating whether the water is acidic or basic.

$$\mathrm{pH} = -\log_{10}(\mathrm{H}^{+}) \tag{1}$$

During photosynthesis, phytoplankton and other aquatic plants remove carbon dioxide from the water, causing the pH to rise during the day and drop at night. Waters with low overall alkalinity typically show pH values between 6 to 7.5 before sunrise, but in the presence of significant phytoplankton growth, evening pH values may reach 10 or even higher [8]. The pH of natural waters is notably influenced by the concentration of carbon dioxide, an acidic gas [4]. pH fluctuations in pond water are primarily influenced by carbon dioxide and ions associated with it. pH control is crucial for reducing ammonia and hydrogen sulphide toxicity [6][9]. Given its direct or indirect connections to various parameters, controlling pH is relatively more manageable. Hence, pH holds the second position in our considerations.

Salinity pertains to the total concentration of electrically charged ions, encompassing both anions and cations, alongside additional constituents. It plays a crucial role in shaping the density and development of the aquatic population [6][4]. However, gauging the concentration of all ions in water is seldom practical. A conductivity sensor can assess conductivity, offering an approximation of salinity. A correlation exists between conductivity and Total Dissolved Solids (TDS) [6][8]. Given that conductivity is affected by ionic concentration and variations in dissolved solids, it is adequate to measure either conductivity or TDS independently. Salinity is the third factor in our considerations.

Dissolved Oxygen (DO) stands as a crucial parameter for consideration. Research indicates that DO levels decrease with rising temperature and salinity (conductivity), while they increase with decreasing temperature and salinity (conductivity). DO also fluctuates in a similar fashion to pH. [6][9][10] Therefore, ensuring that temperature, pH and conductivity stay within the optimal range indirectly maintains Dissolved Oxygen (DO) within the desired levels. Sometimes water color can also indicate the condition of DO in the water body.

The water's color provides insights into various factors; for instance, a greenish hue indicates the presence of a plankton population, while a brown color suggests the existence of clay [6][10]. Clear water signifies low biological production, indicating insufficient fertility for fish development. Muddy water poses risks to fish, potentially obstructing their gills. Dark green water signals an overabundance of plankton, serving as fish food but often resulting from excessive fertilizers, excrement, or nutrient-rich feeds in a pond. Bluish-green, brown-greenish, or light green water hues indicate a beneficial plankton population, promoting the well-being of fish [4][6].

The following table shows the acceptable and desirable range of values of the four key parameters that we have considered [6].

TABLE 1
ACCEPTABLE AND DESIRABLE VALUES FOR THE KEY FACTORS TO BE CONSIDERED FOR AUTOMATION

Parameters	Acceptable	Desirable
Temperature (^oC)	15-35	20-30
pH	7-9.5	6.5-9
Conductivity (µS/cm)	30-5,000	60-2,000
Water Color	Pale green to Light green	Light green to Light brownish green or Bluish green

However, in our automated fish farm, we are going to measure the TDS using a TDS meter because it will help us to get the measure of both TDS as well as conductivity at the same time with a single measurement. Hence, the following equation shows the relation between TDS (in mg/L) and Electrical Conductivity (in µS/cm).

$$\text{TDS (in mg/L)} = \text{k} \times \text{EC (in } \mu\text{S/cm)} \qquad (2)$$

where,

EC – Electrical Conductivity

k – the value of this ratio (TDS/EC) will increase along with the increase of ions in water

However, this relation is not directly linear as it depends on the activity of specific dissolved ions, the average activity of total ions in the water and ionic strength. For natural water the value ranges between 0.55 to 0.85, for seawater (EC between 700 to 25,000 µS/cm) the value is generally 0.7 and for brine water (EC > 45,000 µS/cm) the value is taken to be a value between 0.75 and 0.85 [11].

III. PROPOSED METHOD AND SYSTEMS

Under this we will have two sections. The first one will introduce all the hardware and software components while the second one will propose all the systems that we have used in our research project for the automated fish farm model.

A. Required hardware and software

Our hardware components include:

Arduino UNO: A Microcontroller based on ATmega328P. It has 14 digital I/O pins, 6 PWM outputs, 6 analog inputs, a USB connection, power jack, ICSP header, and reset button. It connects to a computer via USB or powered by AC/DC adapter or battery. [12]

Servo Motor (SG90): It is a DC-powered motor in a closed-loop system. Its working components include motor, potentiometer, gear assembly, control circuit. It ensures precise positioning through positive feedback. [13]

Stepper Motor (NEMA 17): It is a brushless DC motor dividing rotation into steps. It works on open-loop system, controlled by input pulses by phasing with interleaved electromagnets. Hence, it has controlled rotational movement in fixed steps. [14]

Motor Driver Shield (L293D): It consists of H-bridge motor driver IC interpreting signals from microcontroller. It supports up to four DC motors or two stepper motors and has a voltage range of 4.5-25V. [15]

pH Sensor (RC-A-353): It is used to measure pH level of solutions and is compatible with Arduino under 3.3-5.5V DC. It makes use of a BNC probe connector and has a high accuracy of ±0.1. It has a pH detection range of 0-14 and a temperature range of 5-60°C. [16]

LCD: It is a thin and energy-efficient visual display consisting of pixels with RGB subpixels for color display. The LCDs using active matrix (TFT) has superior performance. [17]

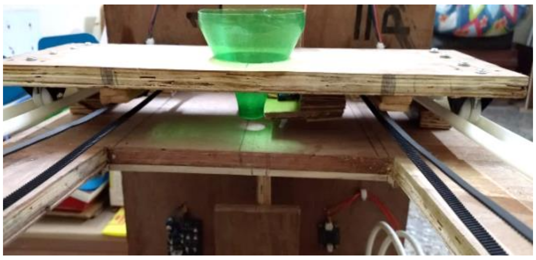
LM7809 IC: It is a fixed voltage regulator IC, accepting 12V as input and providing stable 9V DC as output. The output current is 1.5A with an input range of 11V-35V. It comes with internal thermal and overload protections. [18]

TDS Sensor Module (TDS Meter V1.0): It measures water conductivity and converts it into TDS. It operates under a DC input of 3.3-5.5V and has an output voltage of 0-2.3V. It has a TDS measurement range of 0-1000 ppm. [19]

Color Sensor (TCS3200): It uses a light-to-frequency converter and measures a broad spectrum of colors. It operates on a digital TTL interface on 2.7-5.5V. It uses photodiodes with red, green, blue, clear filters (16 each). [20]

Relay Module (HW 482): It is an electric lever controlled by a small current as it switches larger current in another circuit. It operates on 5V, 10A, 250VAC/30VDC. It has five pins, with high voltage terminals (NC, COM, NO) connecting to the controlled device. In our project, COM connects to NO. When energized, COM connects to NC. [21]

(a)



(b)

Fig. 1. Automated feeding system

Pump (R385): It is a 6-12V DC diaphragm mini aquarium non-submersible water pump and can handle liquids up to 80°C. It provides suction up to 2m and pumps vertically up to 3m. [22]

RS Electric Automatic Aquarium Heater: It is a submersible heater for maintaining stable water 6th International Conference on ‘ Energy Systems, Drives and Automations’, ESDA2023 temperature and consists of a top knob for temperature adjustment (18ºC to 32ºC). It operates at 220V/240V at 50Hz/60Hz and has a rating of 50W. It has durable impact glass and a non-corrosive shell for longer lifespan. [23]

Submersible Thermometer: Digital thermometer with a probe for being placed inside aquarium water. It is used to check and monitor temperature set on the RS Electric Automatic Aquarium Heater. [24]

We have used a software called Python with its library called YOLO v3: Fish detection and counting using YOLO (You Only Look Once) v3 involves using a pre trained neural network model to detect and count fish in images or video frames. It is a real time object-detection system. [25]

B. Implementation of systems

Automated Feeding System: In our model, we utilize one 3-way automatic fish feeder, two stepper motors, and one servo motor. The feeder has three settings: 8 hours, 12 hours, and 24 hours, determining the frequency of feeding. The selection depends on fish type and feeding requirements. The feeder releases food into a container guarded by a servo motor-controlled disc. The container, servo motor, and a movable wooden plank are connected, guided by rails and belt system driven by stepper motors. The sequence involves belt movement, positioning the container, opening, and closing with the servo motor, followed by the return of the wooden plank to its original position for subsequent feedings.

The following figure shows the flowchart and hence the sequence of working of the entire automated feeding system. The delay in between two successive cycles of the automated feeding system is decided by the feeding requirements and the type of fish.

pH Monitoring System: pH is a measure of the acidity or basicity of a solution, expressed as the negative logarithm of the hydrogen ion concentration ($[H^+]$). It typically ranges from 0 to 14 on the pH scale. A neutral solution, like pure water, has a pH of around 7. The formula for calculating pH is

$$\mathrm{pH} = -\log_{10}[\mathrm{H}^+] \text{ or } \mathrm{pH} = -\log_{10}[\mathrm{H_3O}^+] \qquad (3)$$

Solutions with a pH greater than 7 are considered basic, while those with a pH less than 7 are acidic. Temperature influences pH, with its increase leading to a decrease in water pH due to enhanced water dissociation. In the project, a pH sensor is employed, providing continuous readings displayed on a 16x2 LCD screen. Additionally, temperature control is implemented to address the pH-temperature relationship.

Salinity Monitoring System: Salinity refers to the concentration of dissolved salts in water, commonly expressed in parts per million (ppm) or percentage (%). Sodium and chloride are the primary components, with magnesium, calcium, sulphates, and other ions present. The proportions of major dissolved constituents in seawater remain relatively constant, with sodium and chloride ions comprising about 91%. Freshwater has lower salt levels, prompting the use of a Total Dissolved Solids (TDS) sensor in the project.

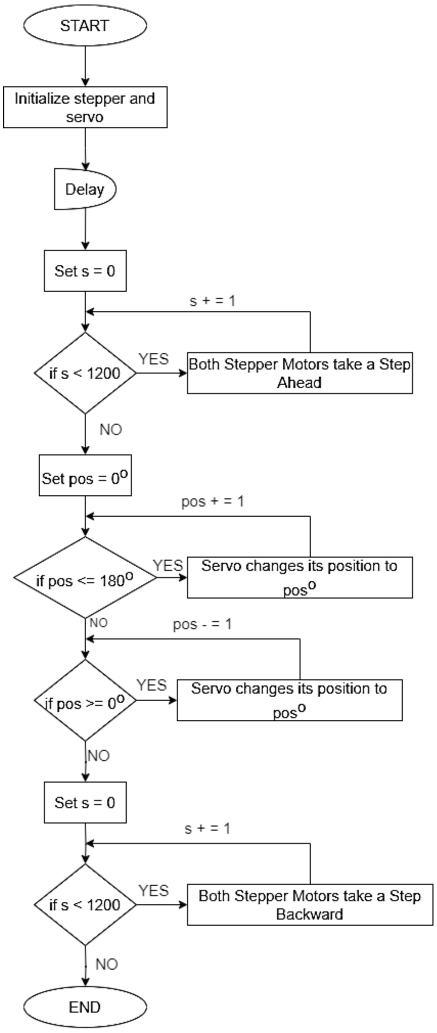


Fig. 2. Flowchart of automated feeding system

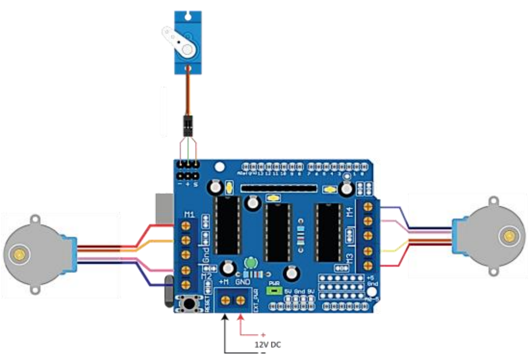


Fig. 3. Circuit diagram of automated feeding system

The TDS sensor, placed alongside the pH sensor in the aquarium, provides continuous readings of dissolved solutes, indicating water cleanliness on the 16x2 LCD screen. TDS measures milligrams of soluble solids per liter of water, with higher values greater solute and reduced Fig. 6. Salinity monitoring system indicating concentration water purity.

Fig. 4. pH monitoring system

Water Turbidity Monitoring and Control System: Turbidity measures the amount of suspended material in a liquid by assessing its light-scattering properties, commonly expressed in Nephelometric Turbidity Units (NTU). Turbidity sensors make use of infrared light to detect suspended particles in water. However, prolonged exposure to infrared light can adversely impact fish, affecting their vision, behavior, and even causing thermal stress. To address this, a color sensor is preferred over a turbidity sensor in this project. The color sensor provides RGB values, allowing assessment of water quality, phytoplankton and algae growth, mud content, and the need for filtration. When values exceed a set range, the filtration system activates through relay modules and pumps, ensuring water quality in the aquarium.

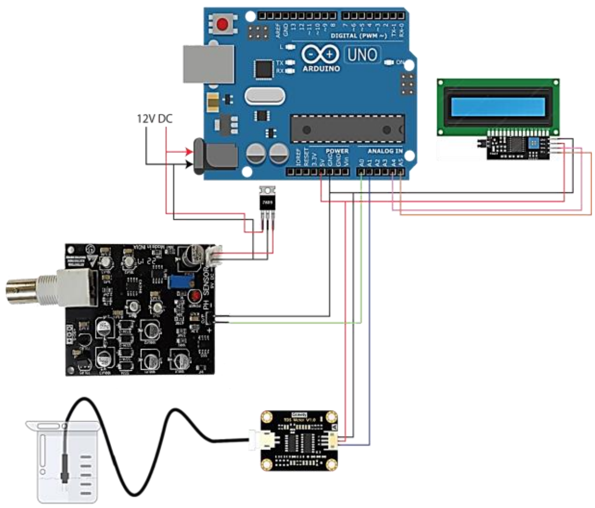


Fig. 5. Circuit diagram of pH monitoring system

Fig. 6. Salinity monitoring system

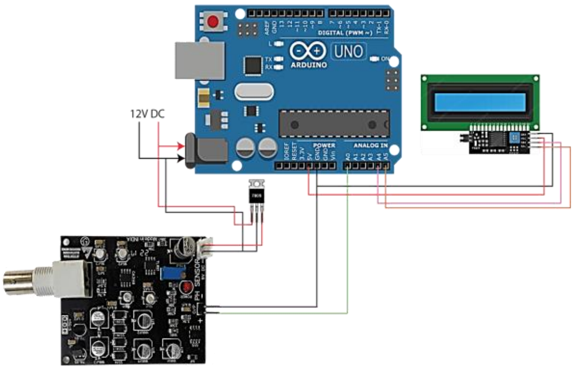


Fig. 7. Circuit diagram of salinity monitoring system

(a)

(b)

Fig. 8. Water turbidity monitoring and control system

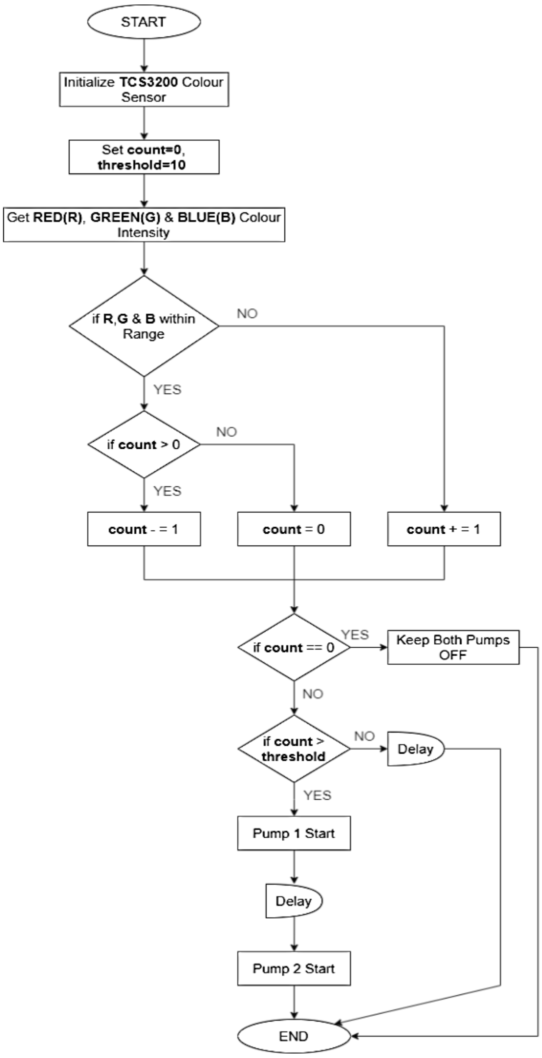


Fig. 9. Flowchart of water turbidity monitoring and control system

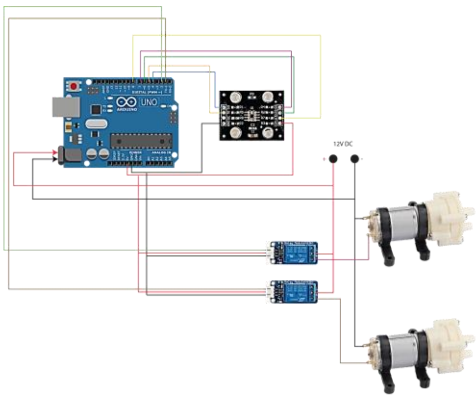


Fig. 10. Circuit diagram of water turbidity monitoring and control system

Temperature Control System: Temperature plays a crucial role in the project, influencing pH, algae growth, microorganisms, and water turbidity. Maintaining a stable temperature is essential. The RS Electrical Automatic Aquarium Heater is employed to uphold a consistent set temperature, while a submersible thermometer ensures continuous monitoring of the maintained temperature in the aquarium water.

Fig. 11. Temperature control system

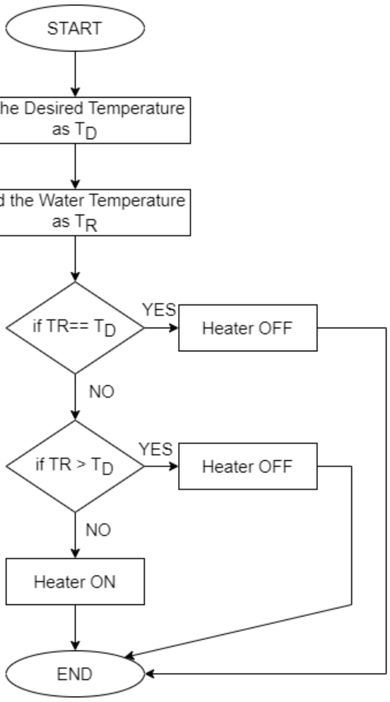


Fig. 12. Flowchart of temperature control system

Water Filtration System: Water filtration system, as discussed earlier, is already a part of the Water Turbidity Monitoring and Control. If the colour sensor detects a deviation from the given range of values, then the relay modules and hence the pumps start operating. Fish Count System: Occasionally, a single harvest from fish farms results in a substantial depletion of fish, leaving the water body with a minimal fish population. Moreover, the harvest may consist mainly of small fish, posing a threat to fish culture and reducing the availability of mature fish for subsequent catches. Therefore, monitoring fish count is crucial. In our project, we aimed to create a simple fish counting system. Using videos captured by a camera, we employ YOLO v3 to detect fish and provide an estimated count.

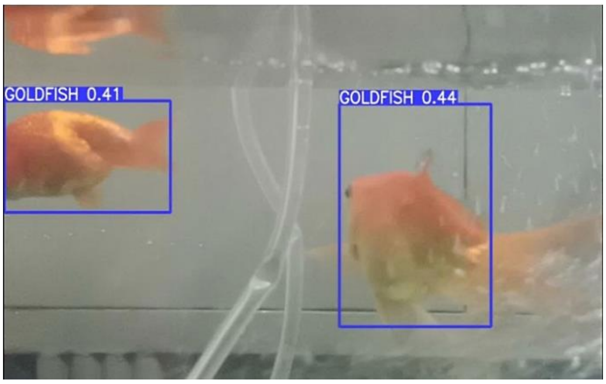
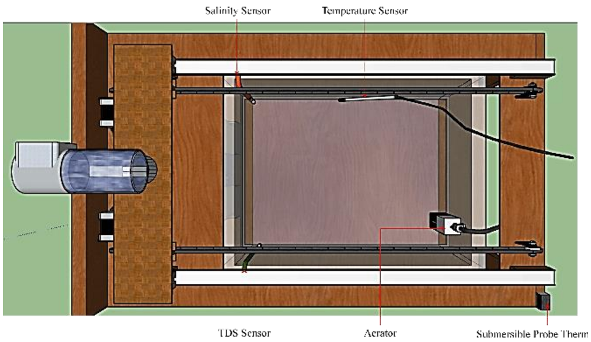


Fig. 13 Fish Detection System.

IV. RESULTS AND DISCUSSIONS

We have made use of a software called SketchUp for the development of the model virtually after which we could get the entire dimensions and design of our physical model. Both the virtual and the physical models are shown along with all the sensors and the hardware components.



Fig, 14 (a)

We use an automatic feeder to feed the fishes 3 times a day and thereby monitor various factors related to the survival of the fishes. TDS sensor and pH sensor measure the salinity and acidic/basic properties of water and activate a pump-relay filtration system if required. We have also used a thermometer that continuously monitors the water temperature and activates a water heater incase the water temperature drops below the desired temperature that is suitable for fish habitation.

The following are the results for two consecutive days (D1 = Day 1 and D2 = Day 2).

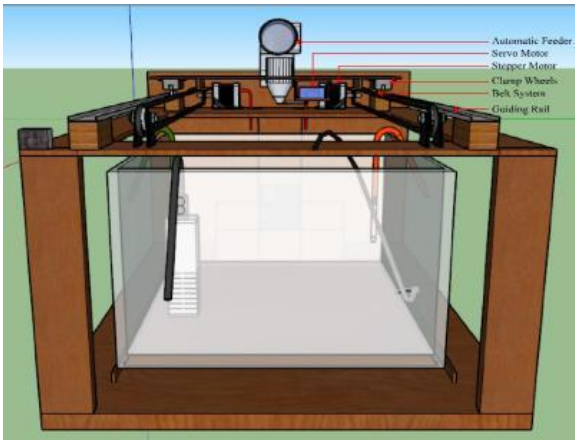


Fig. 14 (b)

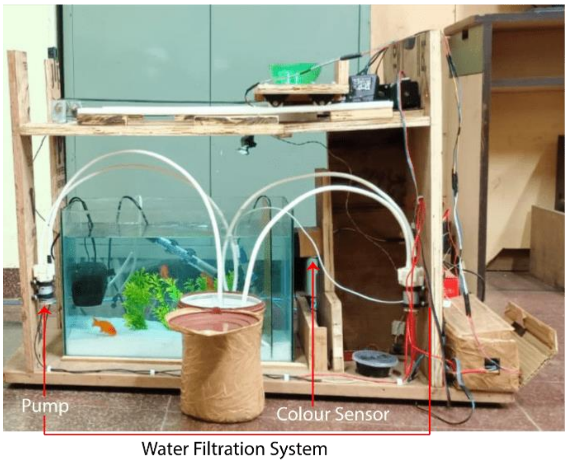


Fig. 14 (c)

Fig. 14. Virtual and physical models

TABLE 2

OBTAINED VALUES FOR TWO CONSECUTIVE DAYS

Time	pH		TDS (mg/L)		Temp. (°C)		Fish Count	
	D1	D2	D1	D2	D1	D2	D1	D2
08:00 AM	7.1	7.3	220.2	230.1	25.4	25.1	4	3
04:00 PM	7.8	7.7	222.4	230.5	25.1	25.0	3	4
00:00 AM	7.6	7.6	227.6	232.9	24.7	24.9	4	4

The automated feeding system provides food to the fish at the timings that are shown in Table 2 and the readings of various other parameters are also taken at that time. The pH values that we have obtained tend to be within the acceptable and desirable values of Table 1. As more and more food is given to the fish, some of the food particles dissolve in the water of the aquarium and hence leads to a change in the pH of the water.

From the TDS values we see that the lowest and the highest values are 220.2mg/L and 232.9mg/L respectively. For freshwater we take the value of k (mentioned in equation 2) to be 0.65 which is almost the average value for the entire range of values that k can take for freshwater aquariums. We now calculate the value of Electrical Conductivity (EC) and find out that it ranges from 338.77 μS/cm to 358.3 μS/cm which is also within the acceptable and desirable range that is mentioned in Table 1.

Temperature is maintained around 25°C. Water colour is light greenish and hence no filtration is needed. Our aquarium had a total of 4 fish and hence we can see that the fish count system needs to be developed further with advanced techniques and machine learning.

V. CONCLUSION AND FUTURE WORK

A. *Conclusion*

Our project has successfully developed a miniature prototype with the capability to detect water pH and total dissolved solids (TDS), monitor and control water temperature, and identify color changes in the water, triggering a filtration process. Our automated fish farm thus consistently generates results within the acceptable and desirable ranges for key parameters, ensuring optimal conditions for efficient, reliable, and secure fish production. This model serves as a miniature version of potential industrial applications for fish farms, indicating its adaptability for larger water bodies used in aquaculture. Future developments include enhancing the communication system for reliable operation and maintenance, as well as implementing machine learning for advanced fish counting - an essential factor for optimizing yields. The project aims to positively impact the fish farming scenario in India and beyond, contributing to increased GDP through exports and enhanced food production. Additionally, it plays a crucial role in wildlife conservation by ensuring the sustainability of fish species that are at risk due to overfishing.

B. *Future work*

In our project, we utilized an aquarium as a demonstration model for the concepts applicable to larger projects like fish farms. The area for fish farming depends on factors such as the type of aquatic species, local water bodies, climate, and rainfall. The systems we employed in our aquarium serve as prototypes for small-scale applications. In large-scale fish farming, modifications and optimizations are necessary for efficiency, cost-effectiveness, and low maintenance. The modifications that are necessary to be implemented are mentioned alongside each of the six systems.

Automated Feeding Procedure: A hexagonal steel structure is proposed for large water bodies. It will use a feeding mechanism moving through the structure, dropping food at designated nodes, taking into consideration the fish behavior, preventing overfeeding, and pH disruption.

pH Monitoring: pH sensors are to be used, hanging from nodes for continuous monitoring, accounting for variations in pH across different water body sections, and strata.

Salinity Monitoring: Placed TDS sensors are to be placed at nodes for measuring total dissolved solids, taking into consideration the variations across different water body sections and strata.

Water Turbidity Monitoring and Control: Initially used color sensors should be replaced with submersible cameras for large water bodies, implementing strategic camera placement to avoid damage and obtain accurate RGB values.

Temperature Control: The water body is to be divided into sections for accurate temperature readings, keeping in mind the thermocline effect in different water layers.

Water Filtration: pH imbalance will be addressed by adding soda ash or muriatic acid as needed. Desirable range of salinity is maintained by combining saline water with fresh water. Water turbidity will be controlled based on RGB values extracted from the live feed of the cameras. Aeration systems should be incorporated to counteract excess cyanobacteria.

Fish Counting: Submersible cameras are also utilized to capture images or videos. These photos or videos will be analyzed by employing OpenCV, Mobilenet SSD, or YOLO v3 for getting the approximate fish count. An AE GSM module is to be integrated for communication, sending alerts to the operator for system malfunctions.

This comprehensive approach ensures effective monitoring and management of various parameters, optimizing conditions for fish health and overall system efficiency in large-scale aquaculture projects, making even some of the endangered species of fish available for a good yield thus leading to wildlife conservation.

ACKNOWLEDGEMENT

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