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The Sustainable Aquqrium: Powered IoT Solution for Effortless Fish care.

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Abstract - The paper presents a smart and compact aquatic system that combines IoT sensors, machine learning, and image processing to automate and optimize aquarium maintenance. The system continuously monitors key water parameters such as turbidity, temperature, conductivity, pH and water level, using sensors interfaced with an STM32 microcontroller. A machine learning model analyzes this data to predict water quality in real time, while a CNN-based image processing module detects fish breed such as Bala Shark, Bristenose Pieco ,Clown Loach, Freshwater Angelfish, Neon Tetra, Silver Dollar and Swordtail and fish diseases from captured images. Additionally, the system features automated fish feeding and water level monitoring for improved care and efficiency. Designed for ease of use, the portable setup is ideal for homes, educational institutions and research environments, offering a realiable and intelligent solution for fish keeping with manual effort.

Index Terms—Sustainable Aquarium, IoT, Water Quality Prediction, Solar Panel Fish Breed Detection, Fish Disease Detection, Machine Learning, CNN, STM32,Automation.

INTRODUCTION

Aquarium maintenance is a delicate task that requires consistent monitoring of water conditions, timely feeding, and early detection of fish diseases to ensure a healthy aquatic environment. Manual management often leads to inconsistency and human error, which can affect the well-being of the aquatic life. To address these challenges, the “Portable Aquarium” project introduces a smart, automated, and compact system that leverages Internet of Things (IoT) sensors and artificial intelligence to simplify aquarium care. This system integrates turbidity, temperature, and conductivity sensors connected to a microcontroller (STM32/Arduino) to collect real-time water quality data. A machine learning model processes this data to predict water quality status, while a Convolutional Neural Network (CNN)based image processing module detects fish diseases from captured images. Additionally, features such as an automatic fish feeder and water level monitoring ensure minimal manual intervention. The portable design makes it ideal for households, educational institutions, and research labs, providing an intelligent and low-maintenance aquatic solution.

RELATED WORK

In recent years, the integration of IoT and artificial intelligence in aquaculture and home aquariums has gained significant attention. Researchers have explored various methods for automating aquarium monitoring systems using sensors that detect water parameters such as pH, temperature, turbidity, and dissolved oxygen. These systems help in reducing manual intervention and improving aquatic life health. Studies show that using microcontrollers like Arduino and STM32 for data collection and control of aquarium hardware has become common due to their low cost, open-source flexibility, and real time processing capabilities. [1]Portable domestic aquarium monitoring and maintenance system with hybrid power source Shanmugapriya A, Mahalakshmi S, Mirnalini P. Automated fish tank system Changing the game in aquarium maintenance, it is a way of providing reliability and convenience when it comes to the care of aquatic pets. For example, integration of IoT technology into a system comprising automated feeding, realtime water quality monitoring, and accessibility over mobile or web interfaces. Sensors track such essential parameters as pH, temperature, and ammonia concentration, permitting the system to learn and adjust conditions accordingly to maintain the relative stability required to keep fish healthy. [2]Precision Aquaculture: An Integrated Computer Vision and IoT Approach for Optimized Tilapia Feeding - Rania Hossam, Ahmed Heakl, Walid Gomaa .This study addresses inefficiencies in fish farming by integrating IoT sensor data with computer vision for automated feeding. Using turbidity and temperature sensors, the system monitors water quality in real time. Simultaneously, the camera captures tilapia images, and a YOLOv8-based model performs key point detection to estimate fish size and weight. The model converts pixel measurements into real-world metrics using depth estimation, achieving a 94 percent precision rate across 3,500 annotated images. [3]IoT Based Environmental Control System for Fish Farms with Sensor Integration and Machine Learning Decision Support - D. Dhinakaran, S. Gopalakrishnan, M. D. Manigandan, T. P. Anish This research designs a wireless IoT sensor network for fish farms, collecting parameters like temperature, pH, humidity, and fish behavior. The data is preprocessed and fed into multiple

ML models— Random Forest for water temperature/pH prediction, SVM for disease detection, GBM for feeding schedule optimization, and Neural Networks for pump/heater control. [4] Prediction Model of Aqua Fisheries Using IoT Devices - Md. Monirul Islam This thesis develops an Arduino-based IoT framework for monitoring pH, temperature, turbidity, and conductivity in fish farm ponds. Data from five ponds are logged to Thing Speak and compared against reference standards. Labels across 11 fish categories are used for multi-class evaluation. Ten ML algorithms (e.g., Random Forest, K-NN, Decision Trees) are compared, with Random Forest achieving the best accuracy (94.42[5] Automatic Water Quality and Fish Feed Monitoring System in Aquarium Using

LoRa - Fariz Ilmi, Syamsudduha Syahrorini, Shazana Dhiya Ayuni, Focused on ornamental fish maintenance, the study deploys Arduino Uno with LoRa SX1278 to monitor temperature, turbidity, and pH. A relay-based water pump keeps turbidity under 2000 NTU. The system also regulates feeding schedules via RTC and servo mechanism, with real-time alerts shown on an LCD. The LoRa communication enables remote dashboard integration, ensuring situational awareness. Functional tests confirm it maintains water clarity automatically. The system offers accessible solutions for home aquariums. [6] Integrating IoT and Deep Learning for Smart Aquaculture Management in Freshwater Aquariums - (ResearchGate source) jurnal.itscience.org . This hybrid study combines IoT water monitoring (pH, turbidity, temperature) using ESP32 with deep learning for three main functions: disease detection, water quality prediction, and fish growth stage classification. The CNN architecture (ResNet50) achieves 99.21 perecent disease accuracy (for Redspot, Whitespot, Tailrot) and 85.5 percent accuracy in fish growth stage prediction.

PROPOSED METHODOLOGY

The design methodology of the "Sustainable Aquarium" project outlines the systematic approach adopted for building a smart, compact, and automated aquarium system. This methodology combines hardware design, IoT integration, machine learning, and deep learning-based image processing techniques to enhance the efficiency and reliability of aquarium management. The methodology was divided into multiple phases—requirement analysis, hardware selection, sensor integration, model development, automation setup, and final integration into a single user friendly system.

a) *System Architecture Design*

proposed system consists of four major functional units:

1. IoT-Based Water Quality Monitoring Unit •Machine Learning-Based Water Quality Prediction Unit •CNNBased Fish Disease Detection Module •Automation Control Unit (Feeder +Water Level Monitoring) All modules are coordinated via a central microcontroller (STM32 or Arduino Uno), which communicates with sensors and controls peripheral devices like motors and cameras. The STM32 is chosen for its built-in Wi-Fi and Bluetooth capability, making it ideal for real-time data transmission and remote monitoring.

b) *IoT Sensor Integration and Real-Time Data Acquisition:*

The initial step in the design process involves the

selection and

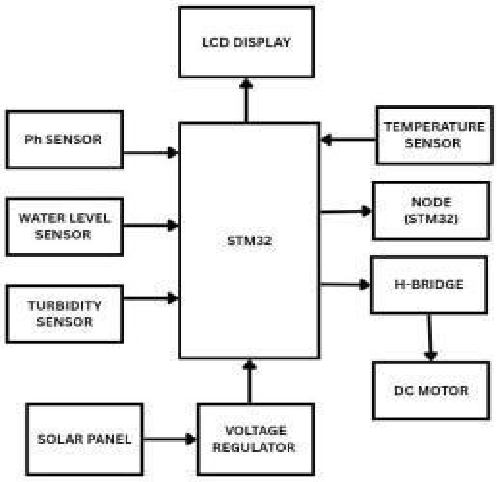

Fig. 1.Methodology

integration of suitable sensors for capturing key water quality parameters: • Turbidity Sensor (TSD): Measures the cloudiness of water to detect pollutants or organic waste.

1. Conductivity Sensor: Assesses the ionic content to determine salinity and overall water purity. • Temperature Sensor (DS18B20): Measures water temperature to ensure it is within the optimal range for fish survival. • Water Level Sensor (Ultrasonic or Float Sensor): Detects the water level to prevent overflows or dry conditions. These sensors are connected to the microcontroller, which reads the analog or digital outputs and converts them into meaningful values using appropriate formulas.

c) *Machine Learning-Based Water Quality Prediction*

To make proactive decisions based on the water parameters, a machine learning model is trained on historical water quality data labeled as "Good, Moderate or Poor". The steps involved are: • Data Preprocessing: Raw sensor values are normalized and cleaned to handle noise or missing entries •Feature Selection: Important features include temperature, turbidity, conductivity, and their variations over time. • Model Selection: Various models like Random Forest, Support Vector Machines (SVM), and Logistic Regression are evaluated. •Training and Testing: The dataset is split (e.g., 80/20) for model training and performance validation. Accuracy, precision, recall, and F1-score are calculated. • Deployment: The best performing model (e.g., Random Forest with 94 percent accuracy) is exported and deployed to the STM32 using tools like TensorFlow Lite Micro or Edge Impulse for real-time inference.

d) *CNN-Based Fish Disease Detection*

..Fish health is monitored using a camera module that captures images of the fish at regular intervals. These images are analyzed using a pre-trained Convolutional Neural Network (CNN) model to detect visible symptoms of diseases such as:

White spot disease • Fin rot • Mouth fungus • Red spot Workflow: • Image Collection: A dataset of healthy and diseased fish images is collected and augmented. • Model Architecture: A lightweight CNN model (e.g., based on MobileNet or custom CNN) is developed using Keras/TensorFlow. • Training Phase: The model is trained using labeled data, with augmentation techniques applied for better generalization. • Validation and Accuracy: The model achieves over 90 perecnt validation accuracy in identifying common fish diseases.

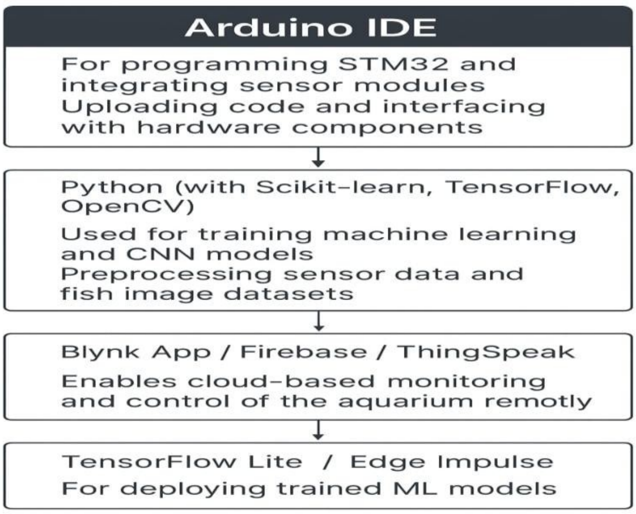

Fig. 2. Software

• Deployment: The CNN model is converted to a lightweight format and integrated with the STM32-CAM or Raspberry Pi module.

e) *Automated Fish Feeding and Water Level Management*

For fish care, the system includes: • Automated Fish Feeder: A servo motor rotates a container with food pellets at predefined intervals. The feeding time and quantity can be adjusted based on fish count or water conditions. • Water Level Alert System: The ultrasonic or float sensor detects when the water level drops

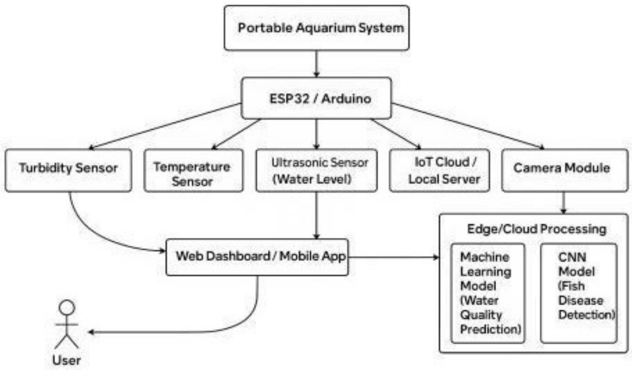

Fig.3.Architecture

Fig. 4. Flow Diagram

Optionally, a pump can be turned on to refill the tank automatically from a reserve container.

f) *User Interface and Remote Monitoring*

A mobile app or web dashboard is developed using Blynk or Firebase to allow users to: • View real-time sensor values and

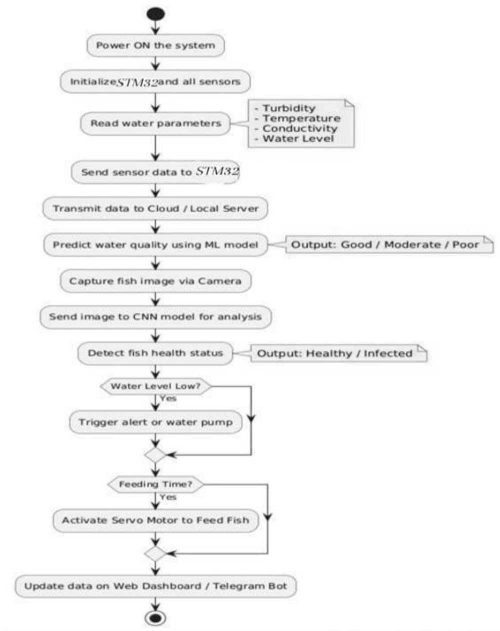

Fig.5.Parameters Display

water quality status. • Receive disease alerts with captured fish images.

g) *System Integration and Testing*

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The final phase includes assembling all modules into a compact and portable aquarium prototype. The entire system is powered using a 12V adapter with voltage regulators for individual components. Rigorous testing is conducted under various water conditions to: • Validate sensor accuracy and response time. • Confirm prediction model reliability. • Ensure correct operation of the CNN-based image detection. • Verify mechanical components like the feeder and pump

RESULT AND ANALYSIS

The proposed Sustainable Aquarium system is expected to deliver a fully integrated, intelligent solution that simplifies and enhances the care of aquatic life through automation, machine learning, and IoT-based monitoring. The system aims to minimize human intervention while maintaining optimal living conditions for fish and other aquatic organisms. The anticipated outcomes are as follows:

1. Real-Time Monitoring of Water Parameters: The system will successfully monitor key water quality parameters in real time using IoT-enabled sensors such as temperature, turbidity, conductivity, and water level sensors. These values will be logged and visualized through a display unit or mobile application, enabling the user to stay informed about aquarium conditions at all times.
2. Accurate Prediction of Water Quality Using Machine Learning: By analyzing the live sensor data through trained machine learning models, the system will accurately predict the overall condition of the water (e.g., Good, Moderate, Poor). This predictive insight will allow proactive maintenance, reducing the risk of fish stress or mortality due to sudden deterioration in water quality.
3. Automated Feeding and Water Level Management: The system will feature an automated fish feeder operated by a servo motor, which will dispense food based on pre-defined schedules or live data conditions. It will also include water level monitoring using ultrasonic or float sensors, with alerts or automatic refill features triggered when levels fall below the threshold.
4. Early Detection of Fish Diseases Using Image Processing: A CNN-based image analysis model will be implemented to detect visible signs of common fish diseases. By capturing and analyzing images using an integrated camera module, the system will generate alerts for early treatment and prevent the spread of illness within the tank.
5. User-Friendly Interface and Alerts: Through mobile applications like Blynk or cloud services like Firebase/Thing Speak, users will be able to view system data, receive real-time alerts for water quality issues or disease detection, and even control functions such as feeding from a remote location. This adds portability, convenience, and assurance to the aquarium management experience.
6. Reduction in Manual Effort and Enhanced Fish Welfare: The system will significantly reduce the need for manual intervention in regular maintenance tasks, offering a reliable and intelligent aquarium management solution. This will benefit not only hobbyists but also researchers, educators, and commercial fish keepers by ensuring stable environmental conditions and improved aquatic life welfare.
7. Scalability and Adaptability: The architecture of the system is designed to be modular and scalable, making it adaptable to different sizes and types of aquariums. It can be further extended to support additional features like pH monitoring, automated lighting, or even water filtration controls in the future.

Fig.6.Software Output

1

Fig. 7. Software Output 2

Fish breed detection: Fish breed detection is an image based identification system that automatically recognizes different aquarium fish species using computer vision and machine learning techniques. The system analyzes features such as body shape, color patterns, fin structure, and size to accurately classify each fish into its respective breed.

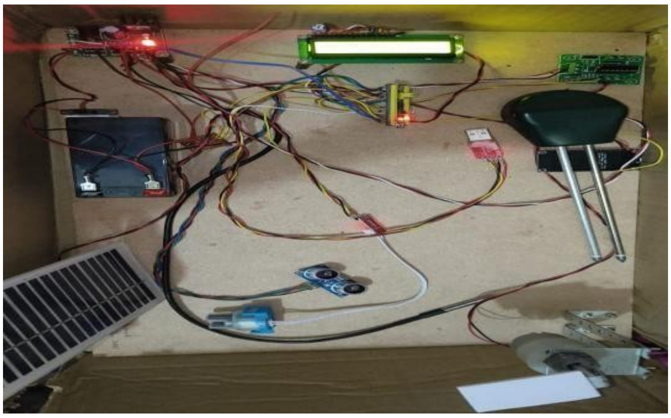

Fig. 8. Hardware Setup

The model is trained using a dataset containing images of popular aquarium fish species, including:

Bala Shark – Identified by its torpedo-shaped body, silver coloration, and distinct black-edged fins.

Bristlenose Pleco – Recognized by its flattened body, sucker mouth, and signature bristle-like growths on the snout.

Freshwater Angelfish – Characterized by its triangular body, long flowing fins, and vertical black stripes.

Neon Tetra – Detected using its bright blue horizontal stripe and vibrant red tail section.

Silver Dollar – Known for its round, disc-like silver body resembling a coin.Swordtail – Identified by the elongated lower tail fin in males, resembling a sword.

CONCLUSION

The Sustainable Aquarium project presents a comprehensive solution for modern, intelligent fish tank management by integrating IoT sensors, machine learning algorithms and computer vision techniques. Through the use of real-time water quality monitoring, automated feeding, water level control, and fish breed detection,fish disease detection via CNN-based image processing, the system minimizes manual intervention and enhances aquatic animal welfare. The predictive capabilities of the machine learning model allow early identification of unfavorable water conditions, enabling timely corrective actions and ensuring a healthier living environment for the fish. Additionally, the system's remote monitoring functionality, powered by platforms like Blynk or Firebase, adds convenience and portability, making it ideal for home users, researchers, and educational setups. The modular and scalable design of the project ensures that it can be adapted to different aquarium sizes and extended with new features in the future. Overall, this project serves as a valuable step toward smart, sustainable aquarium automation using emerging technologies.

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