

Smart Feeder Aquarium and Water Quality Monitoring using Raspberry PI and Blynk

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Abstract

The Smart Pet Feeder system is an innovative solution designed to automate pet care, particularly for aquatic environments, by integrating sophisticated sensor technology and artificial intelligence. The system features a pH sensor and a turbidity sensor, both critical for maintaining optimal water conditions for fish. The pH sensor continuously monitors the water's acidity or alkalinity, ensuring that it remains within a healthy range specific to the species of fish being cared for. This is crucial because even slight deviations in pH levels can lead to stress, illness, or even death in fish. The turbidity sensor, on the other hand, measures the water's clarity by detecting suspended particles such as uneaten food, waste, or algae. High turbidity levels can reduce water quality by lowering oxygen levels and increasing the risk of disease. To further enhance the system's functionality, the Smart Pet Feeder incorporates the YOLOv5 model, a cutting-edge deep learning algorithm known for its speed and accuracy in real-time object detection. YOLOv5 is utilized in the system to monitor the movement of pets, specifically fish, within the aquarium. The model processes the video feed from a built-in camera and detects when the fish are active, ensuring that the feeding mechanism is triggered only when the fish are in motion and near the feeding area. This approach not only reduces food waste but also prevents overfeeding, which can lead to poor water quality and health issues in fish. The entire system is built around a Raspberry Pi 4 Model B microcontroller, which serves as the central hub for processing data from the sensors and controlling the feeding mechanism. During evaluation, the system demonstrated high effectiveness in automating the feeding process and maintaining optimal water conditions, with the sensors providing accurate readings and the YOLOv5 model delivering precise motion detection. In conclusion, the Smart Pet Feeder system represents a comprehensive and advanced approach to pet care. By combining precise sensor technology with intelligent AI-driven motion detection, the system ensures that pets, particularly fish, are fed appropriately and live in a well-maintained environment. This not only simplifies the responsibilities of pet owners but also significantly enhances the health and well-being of their pets, providing peace of mind even when they are away from home.

1. Introduction

People are often so busy with their livelihoods that they have little time for personal interests, like spending time with loved ones and pets. Despite a deep love for animals like fish, dogs, cats, and rabbits, modern life can cause people to overlook pet care responsibilities, especially feeding on schedule [1]. Pet care involves more than just being with pets; it requires real concern and ensuring they are fed on time and in the right amount. Unfortunately, many lack the knowledge needed to meet their pets' nutritional needs, making feeding a difficult and time-consuming task. As awareness of this problem grows, there is increasing demand for creative solutions that fit busy lives and ensure pets' wellbeing [2].

Aquarium keeping is a popular hobby that provides aesthetic pleasure and relaxation. However, maintaining a healthy aquatic environment requires careful attention to feeding schedules and water quality. Traditional feeding and water quality monitoring methods can be time-consuming and prone to error, leading to health risks for fish [3]. Feeding fish at regular intervals and monitoring water parameters like pH, temperature, and ammonia levels can be overwhelming for busy individuals [4]. Inconsistent feeding and poor water quality can cause health problems, stress, and even death in fish [5].

Recent advancements in technology have led to the development of smart aquarium systems that integrate automated feeding and water quality monitoring. These systems use sensors, microcontrollers, and mobile apps to provide a seamless and user-friendly experience for aquarium keepers [6]. Smart feeders can be programmed to dispense food at set times, while water quality sensors continuously monitor and report key parameters. Alerts can be sent to the owner's smartphone, ensuring prompt attention to any issues. This research introduces the Smart Aquarium System, which ensures timely feeding and maintains water quality in the aquarium [7]. The automated functions of the Smart Pet Feeder help maintain a regular feeding schedule, benefiting the animals' health and providing convenience for pet owners [8].

The Smart Pet Feeder combines a Raspberry Pi, a servo motor, and a food storage unit for automated operations. It also features a built-in camera, allowing pet owners to monitor their pets via smartphones. This added feature enhances the Smart Pet Feeder's functionality, providing immediate visual insights into pets' health, strengthening connections, and ensuring an improved pet care experience [8][9].

2. Methodology

The Smart Fish Feeder system is an advanced, automated solution designed to optimize the aquaculture environment for goldfish by maintaining water quality and ensuring proper feeding practices. This chapter provides a detailed exploration of the various components, methods, and technologies that make the system effective. Central to the system is the integration of sensors for continuous monitoring of water quality, particularly focusing on pH and turbidity levels. The pH sensor tracks the acidity or alkalinity of the water, which is crucial for the health of goldfish, while the turbidity sensor monitors water clarity to detect the presence of particles like uneaten food or waste. Both sensors are meticulously calibrated to provide accurate real-time data, which the system uses to maintain a stable and healthy environment for the fish.

The Raspberry Pi 4 Model B microcontroller serves as the core of the system, processing the sensor data and controlling the feeding mechanism. The chapter delves into the programming of the Raspberry Pi, explaining how it interprets sensor data, stores historical information, and triggers the feeding mechanism based on specific conditions. To ensure that feeding occurs only when necessary, the system employs the YOLOv5 model, a state-of-the-art deep learning model for real-time object detection. This model has been trained to detect goldfish movement, and it triggers the feeding mechanism when the fish are active and near the feeding area, thereby reducing food waste and maintaining water quality.

In addition to these features, the system integrates the Blynk application, a smartphone-based interface that allows for remote monitoring and control. Through the Blynk app, users can customize alerts for pH and turbidity levels, adjust feeding times, and even manually trigger the feeder. The app also provides graphical representations of sensor data over time, helping users track trends and make informed decisions about their aquaculture setup. The chapter covers the setup and calibration of all system components, including sensors, the Raspberry Pi, the YOLOv5 model, and the Blynk app, ensuring that the system operates seamlessly.

Overall, the Smart Fish Feeder system enhances the health and growth conditions for goldfish by providing a precise, efficient, and user-friendly solution for aquaculture management. The chapter concludes with a discussion of potential future enhancements, such as integrating additional sensors for more comprehensive water quality monitoring and improving the machine learning model for even more accurate motion detection. Through this detailed explanation, the chapter underscores the system's innovative approach to maintaining an optimal environment for goldfish.

2.1 Flowchart of The Process

This research was conducted based on two flowcharts, as shown in Fig. 1 and Fig. 2. The first part of the study presents the system flowchart, illustrating the software process for YOLOv5 during the project. The second part

of the study shows the hardware system flowchart, detailing the hardware components and their interactions throughout the project's duration.

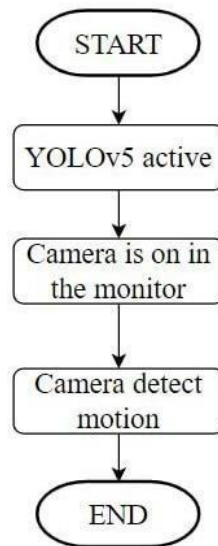


Fig. 1 Software process for the YOLOv5

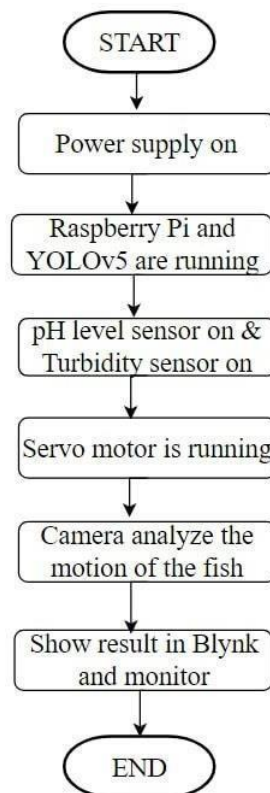


Fig. 2 Hardware process for Smart Aquarium System

2.2 Block Diagram for The Process

Fig. 3 shows a simple block diagram of the procedures needed to use an Android app to control a sensor, servo motor, and camera. The main goal of this project is to monitor and control the feeding system using a smartphone. An application has been developed using the Blynk platform to achieve this. The app allows users to control the components by clicking on graphical buttons, each of which is assigned a specific function based on the load input from the microcontroller. To participate in this activity, a smartphone running the Android operating system must have the app installed.

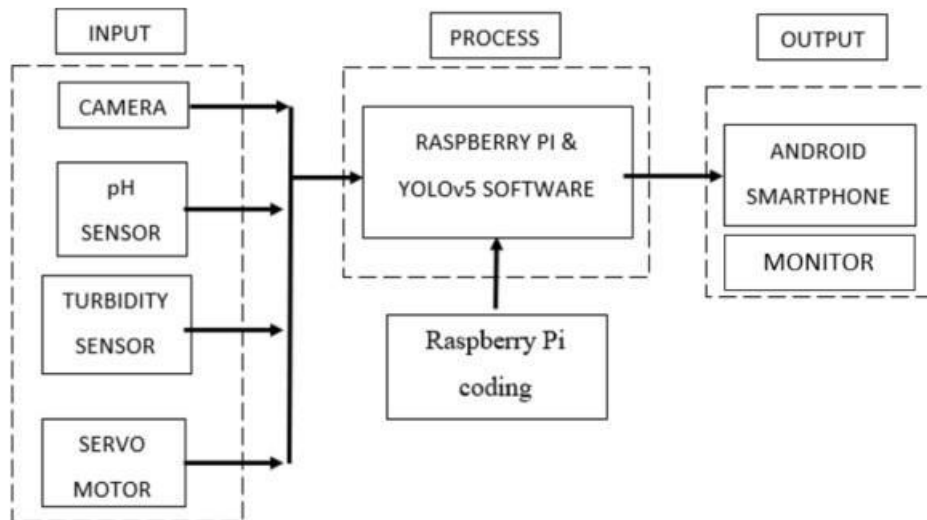


Fig. 3 Block diagram of the process Smart Aquarium System

Next, the Raspberry Pi was a key component that was used to programme, read, and send signals. The coding that will be programmed needs to be inserted correctly in order to avoid mistakes during upload into the board. If the code that is uploaded to the Raspberry Pi board is successful, the led will blink. Using an Android smartphone and an IoT platform and Wi-Fi, the components can be controlled as a final outcome of the process.

2.3 Packaging Design Box

A protective covering made to protect electrical connections and components from moisture, dust, water, and other external factors is called a water-resistant junction box. These boxes are frequently utilized in damp, outdoor environments where there's a possibility of rain, water splashing, or excessive humidity. A water-resistant junction box's main role is to keep out water intrusion, which would otherwise cause corrosion, short circuits, or electrical problems. The junction box is shown in Fig. 4.

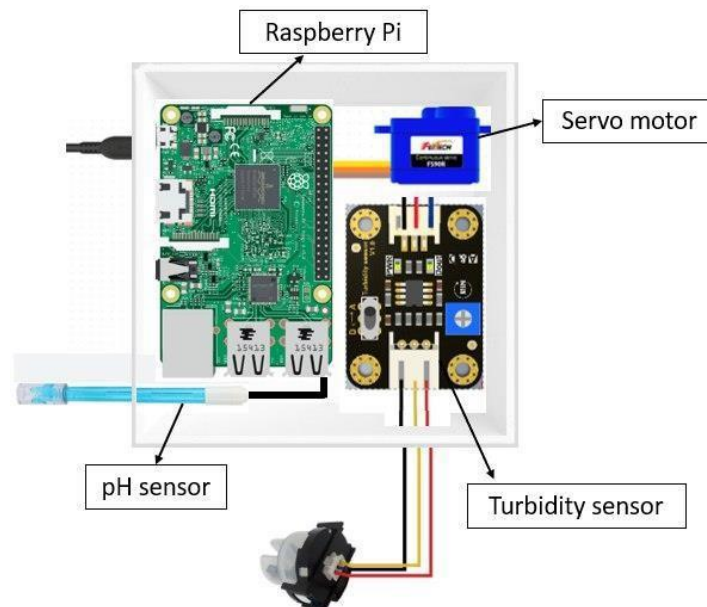


Fig. 4 Top view of packaging design box

2.4 Prototype Development

The finished prototype displays the functionality, features, and design of the product in its fully realized state and acts as a guide for production or development. Ornamental fish aquaculture is displayed in the clear container along with some objects such as the junction box which all the sensor is placed inside along with power supply as shown in Fig. 5.

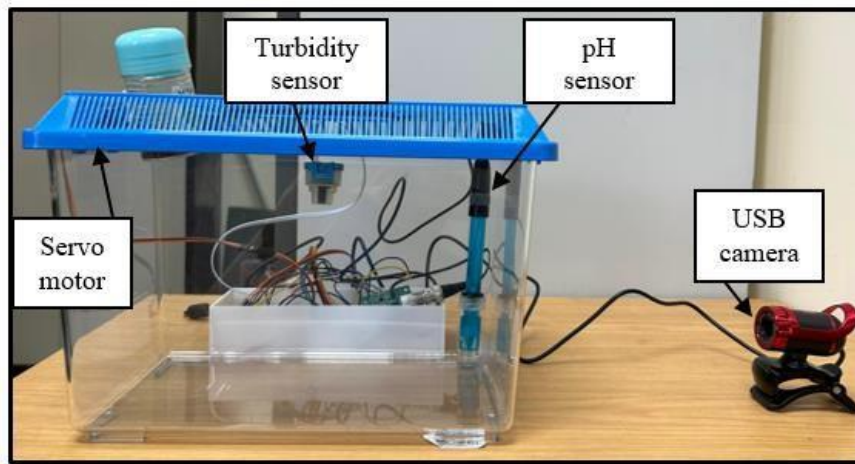


Fig. 5 Front view of project design

3. Result and Discussion

The methodical and crucial process of sensor testing is designed to evaluate and confirm the accuracy, dependability, and performance of sensors. Sensors, which are essential for identifying and quantifying physical characteristics or alterations in their surroundings, are carefully inspected to guarantee accurate operation across a range of circumstances.

When evaluating sensors, several important factors are examined. Sensitivity, or a sensor's capacity to recognize minute variations in input, is assessed closely. Response time is another important factor to consider. It shows how quickly a sensor responds to stimuli. Furthermore, a detailed analysis is conducted of the sensor's performance under various environmental circumstances, including changes in temperature and humidity. A crucial stage in sensor testing is calibration, which entails adjusting the sensor's output to match a recognized standard. This guarantees that the sensor will continuously produce results that are reliable and consistent. It's also a standard procedure to put sensors through performance testing, which involves simulating scenarios, to determine how accurate and reliable they are in real-world settings.

3.1 pH Sensor Testing

To ensure accuracy, testing a pH sensor involves several crucial steps. First, create sample solutions with different pH levels by immersing fish pellets in water over several days to simulate various water conditions. Inspect the sensor for physical damage and ensure the electrode and reference junction are clean. Test the sensor's stability and sensitivity to pH changes by submerging it in sample solutions. Perform a zero-point check at pH 7.00 to verify precise measurements. Assess the sensor's response time and accuracy by comparing its readings with known pH values. Regular maintenance, cleaning, and meticulous record-keeping are essential to maintain the sensor's accuracy and reliability. Fig. 6 illustrates the testing process.

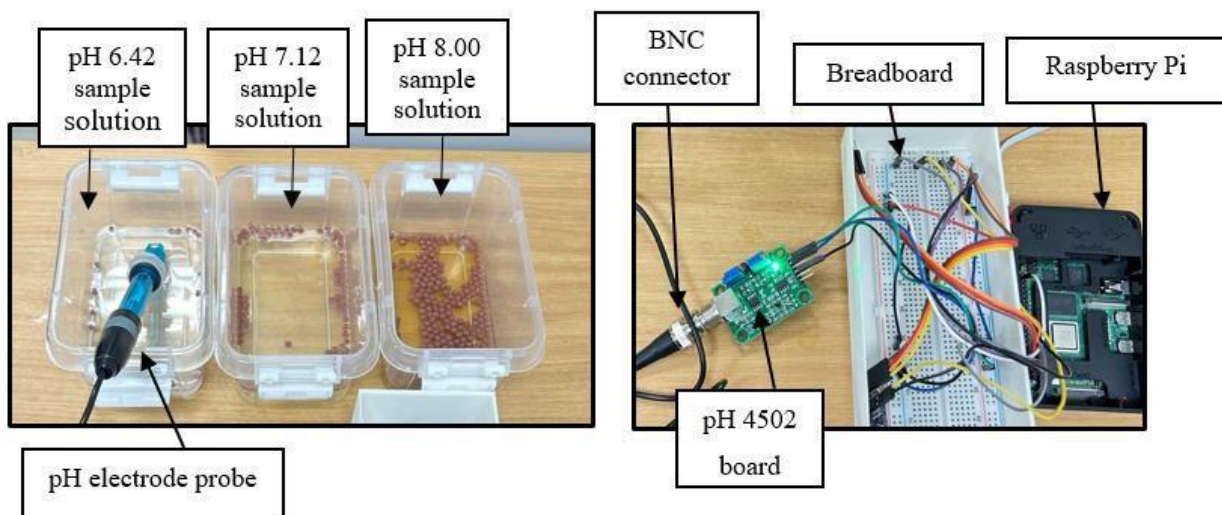


Fig. 6 Connection for pH sensor testing along with its sample solution

Fig. 4 depicts the setup of a pH sensor module E-201-C, utilizing an analog probe connected to an ADS1115 converter for analog-to-digital conversion, necessary because the Raspberry Pi lacks analog pins. Calibration involves adjusting the offset potentiometer near the BNC connector to set the pH 7 reading precisely to 2.6V. Shorting the BNC connector replicates a neutral pH (pH 7), followed by fine-tuning the offset potentiometer until the output voltage (V_{out}) reaches 2.6V.

Table 1 Recorded values using pH sensor

Type of sample solution	Value in Blynk	Value in serial monitor
1	6.42	6.55
2	7.08	7.12
3	7.92	8.00

Based on the recorded values from three different sample solutions in Table 1, the pH sensor measurements are not accurate due to fluctuations in the sensor's performance and exposure to contaminants in the water. Improper maintenance and infrequent calibration can further degrade the sensor's performance, resulting in erroneous pH measurements. Accurate pH measurements depend on careful shielding, regular calibration, proper maintenance, and minimization of external influences.

3.2 Turbidity Sensor Testing

Testing turbidity sensors involves comparing them with reference methods, verifying their performance in various conditions, and calibrating those using standard solutions. Precise measurements are ensured by evaluating their dynamic range, susceptibility to interference, and stability. Thorough documentation and routine testing are essential, especially in applications like water quality monitoring and treatment.

Turbidity sensors are calibrated using standard solutions that represent different turbidity levels. These solutions mimic real-world conditions and serve as benchmarks for calibrating and verifying sensor accuracy. Standard solutions cover a range of turbidity values, providing a basis for assessing how well turbidity sensors perform in different environmental conditions, as depicted in Fig. 7.

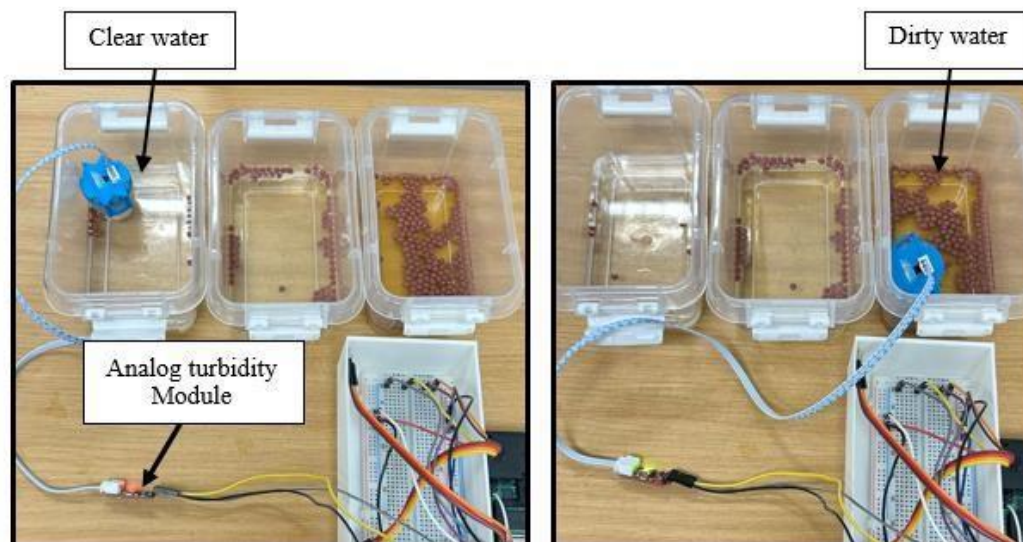


Fig. 7 Circuit Connection for Analog Turbidity Sensor

Calibrating a turbidity sensor involves adjusting it to match known turbidity levels using reference solutions of clear and cloudy water. This process ensures the sensor delivers accurate and consistent readings. After calibration, the sensor undergoes testing to verify its accuracy and reliability across various turbidity levels. Testing involves comparing sensor readings with the known turbidity levels of standard solutions to confirm its performance.

Table 2 Recorded values using Turbidity sensor

Type of water	Value in Blynk	Value in serial monitor	Turbidity voltage
Clear	-1	-2	-1
Dirty	0	1	1

The value recorded in Table 2 is not accurate due to the fluctuation in the sensor reading. It shows that the reading is not stable due to the presence of interference such as noise from electronic devices such as phone and laptop. Therefore, several steps have been taken to minimize the issues.

3.3 Outcome of YOLOv5

After successfully training a YOLOv5 detection model with a dataset of goldfish images, the trained model is saved as an inference file. This file captures the best results from the 70 training epochs. To perform inference, use these weights along with a configuration file that sets the model confidence level. Higher confidence requirements lead to fewer predictions. The inference setup can handle directories of images, individual images, video files, and webcam feeds from devices.

Fig. 8(a) and 8(b) illustrate that the model achieves higher accuracy when detecting goldfish in clear and less crowded images. In Fig. 8(a), where goldfish are clearly visible, the model identifies all of them accurately. Conversely, in Fig. 8(b), some goldfish are missed, possibly obscured by others or due to high fish density. This highlights the importance of image clarity and fish quantity for optimal model performance.



Fig. 8 Prediction result from saved model for (a) fewer (b) plentiful

Additionally, YOLOv5 can accurately count the number of fish detected in a single image, as shown in Fig. 9(a). This counting capability is crucial for monitoring and managing fish populations in tanks. Fig. 9(b) further demonstrates YOLOv5's ability to detect goldfish. By ensuring accurate identification and counting of fish, YOLOv5 supports maintaining a healthy environment, preventing overcrowding, and ensuring each fish has adequate space and resources.

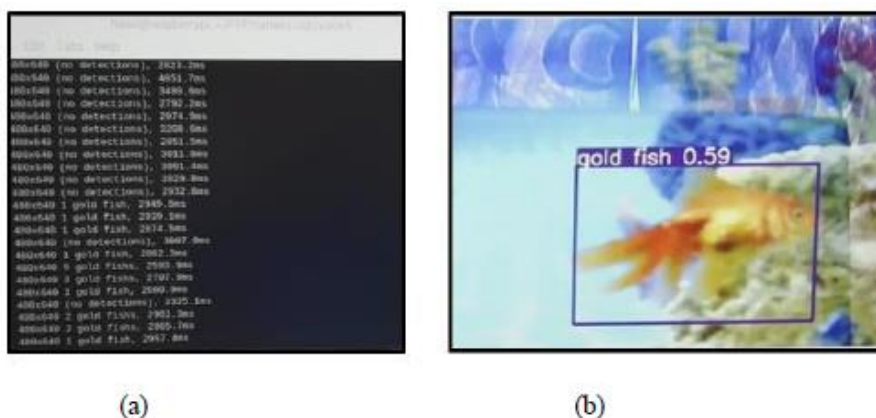


Fig. 9 Output YOLOv5 (a) Serial monitor (b) Counted fish

3.4 Comparison outcome of YOLOv5

To determine whether YOLOv5 can detect only goldfish or if it can also identify other animals, a variety of samples were tested. Table 3 presents the results of using YOLOv5 on a range of different animals, including sharks, octopuses, whales, dolphins, and crabs. This broader testing approach helps to evaluate the model's ability to accurately detect various creatures beyond just goldfish.

By examining the performance of YOLOv5 on these different animals, it becomes possible to assess whether the model can effectively recognize and identify a wide range of species in different images. Fig. 10 shows the type of animal are not detected using YOLOv5.

Table 3 Result of using YOLOv5 on a range of different animals

No.	Type of animals	Detect or not
1	Gold fish	Detected
2	Octopus	Not detected
3	Whales	Not detected
4	Dolphins	Not detected
5	Crabs	Not detected
6	Sharks	Not detected

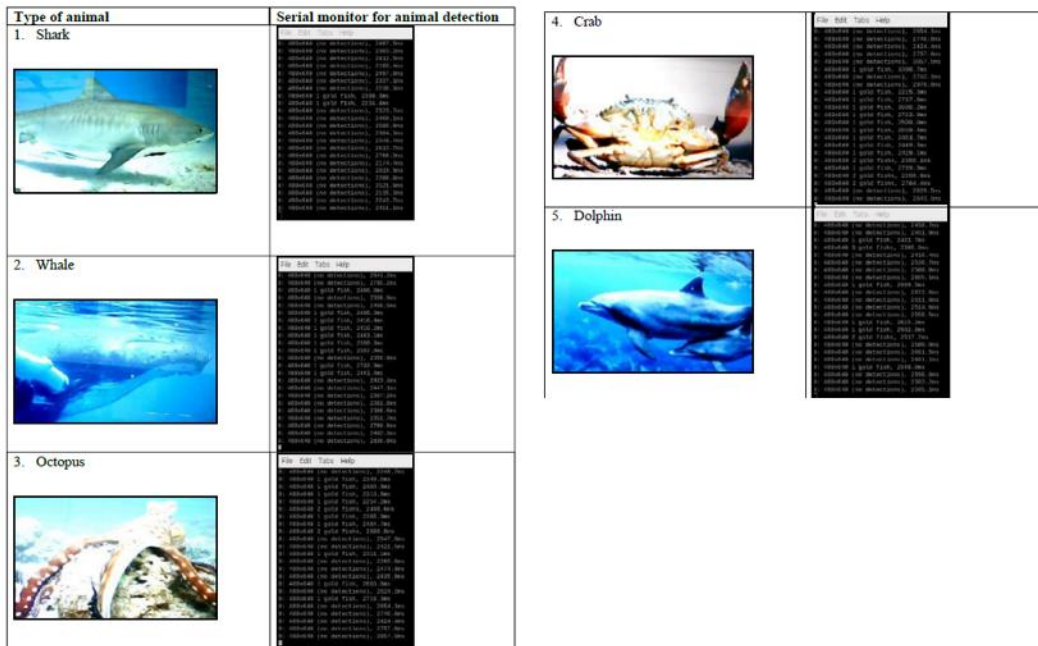


Fig. 10 Result not detected using YOLOv5

4. Conclusion

In conclusion, this study successfully addressed the key aspects of monitoring an aquarium by designing, developing, and evaluating a smart feeding and water quality monitoring system. Using Fritzing software, we created a robust framework to manage feeding schedules and monitor water quality, ensuring the system met the fish's needs. This smart device simplifies pet care by allowing owners to check on their pets in real-time through a built-in camera and smartphone connection. Testing demonstrated that the Smart Pet Feeder reliably dispenses the correct amount of food and maintains water quality, proving that smart devices can make pet care easier and more efficient.

Performance analysis confirmed the system's efficiency and reliability, showing that it could operate autonomously with minimal human involvement. This reduces the chance of mistakes and ensures a stable and healthy environment for the fish. The study demonstrates that smart technology can significantly enhance pet care, making it more manageable and effective for pet owners.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** *Putera Mohamad Nasri, Danial Md Nor*; **data collection:** *Putera Mohamad Nasri*; **analysis and interpretation of results:** *Putera Mohamad Nasri, Danial Md Nor*; **draft manuscript preparation:** *Putera Mohamad Nasri*. All authors reviewed the results and approved the final version of the manuscript.

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