Smart IoT-based Feeder System for Koi Fish (Cyprinus rubrofuscus) Aquaculture

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***Abstract*— Aquaculture is a method of cultivating marine life from coastal waters for the purpose of producing food, commercial products, and restoration of the water ecosystem. The adoption of technologies provided innovative approaches, particularly in the realm of Industry 4.0 in enhancing the efficiency and sustainability of aquaculture practices. This research focuses on incorporating an IoT-based feeder system for koi fish (Cyprinus rubrofuscus) which aims to monitor the environment and control the quantity of food given to the school of fish. This system comprises IoT sensors, actuators, and microcontroller units linked to the internet for surveillance of waterlife quality optimal for the growth and cultivation of the fish. The main components of the system are Raspberry Pi and ESP32 microcontrollers, water quality sensors and servo motors. The integrated software is programmed for a timely feeding cycle and instant data processing. The installed systems, such as ThingSpeak, allows remote monitoring and control providing the agriculturist analytical data and instruments for the visualization of the tank control and feeding schedules. As such, the application of the IoT technology in aquaculture leads to a progression in cultivating fish farming through a customizable intelligent feeder system. Moreover, incorporating an intelligent feeder system increases the efficiency in productivity for fish farming achieving a more sophisticated and sustainable aquaculture management practice.**

Keywords*— *aquaculture, feeder system, koi fish, IoT

I. Background

Technologies continue to progress across various fields, including smart manufacturing, also known as Industry 4.0. Smart manufacturing integrates advanced technologies to meet the demands of production in manufacturing industries. This involves incorporating actuators, sensors, mobile devices, and computers connected to W-Fi, Bluetooth and other available networks for fast-paced communication systems. This arrangement is commonly referred to Internet-of-Things (IoT) systems [1].

IoT networks are divided into segments, devices, gateways and cloud [2]. In the category of devices, actuators, sensors and other physical technologies are grouped together while gateways are what bridges devices to a network, and these may be physical. devices or software. The cloud on the other hand is the remote server that accesses the internet. This allows users to manage and store their data on the internet in exchange for storing data locally to their devices and servers.

These system networks are powerful technologies which can aid the advancement of agriculture. Agriculturists are encouraged to integrate technological innovations to match the world's demands, therefore making it difficult to monitor the livestock as it requires manual labor. The integration of IoT helps in automating tools to monitor the conditions of a farming environment, such as supervising the parameters of temperature, humidity, soil and water level [2]. With this information, cultivators in aquaculture can adapt the system of IoT to improve the management of aquatic organisms as it is necessary that their environmental conditions be monitored and increase their growth in population and size.

A study developed an IoT-based system while utilizing a Raspberry Pi to monitor the water conditions for shrimp farming. This is aimed to focus on the surveillance of water temperature and level. The microcontroller manages the aerators, turning them on or off as needed. [3]. Additionally, another study employed a low-power wide area (LPWAN) to wirelessly monitor and transmit data on water quality from sensor modules addressing the limitations of associated wireless technologies [4].

In [5], a group of researchers employed a water quality control system that is specifically designed for a fishpond for St. Peter's Fish, also known as Tilapia. It features a treatment system which is monitored with the interference of mobile devices for a comprehensive monitoring system. Parameters included in tracking the quality of life of these fish are pH, temperature and dissolved oxygen. These will activate the treatment system when suboptimal conditions are detected facilitating real-time monitoring through the Blynk app. This enables effective wireless communication with IoT devices. Another study has explored the use of this method, where a mobile cloud is utilized for data collection and transmission in aquaculture systems in efforts to enhance existing automatic feeding methods. These methods can be integrated with computer vision to further monitor the movement of fish in or near feeding areas to ensure and observe their appetite [7]. Table 1 shows the summary of the literature review.

TABLE I. RELATED LITERATURE

No.	Research Problem	Technology
[1]	Use of IOT to alleviate concerns primarily on the amount of food fed to the target aquatic species cultured to maximize growth	industrial IoT
[2]	Use of cloud computing to address the concern related to warehouse management of koi-fish breeding	cloud computing
[3]	Shrimp farming optimization through a comprehensive sensory monitoring of growth shrimp parameters	cyber-physical system
[4]	A mobile device network surveillance system for remote monitoring and access of farm information for the to address food insecurity	mobile technologies
[5]	Use of image processing and optimization of water quality parameters to address poor water quality	cloud manufacturing
[6]	Affordable feeder mechanism for fish feed automation addressing cost of production of a feeder system for aquaculture	rapid realization of products

This paper aims to design an intelligent feeder system for koi fish, utilizing the performance of IoT network systems. For surveillance of the water for the tank quality, this project is utilizing IoT sensors. Additionally, an automatic feeding system is constructed for a timely manner of feeding the fish.

II. Theoretical and Conceptual Framework

A. Theoretical Framework

Figure 1 displays the theoretical framework of the study that summarizes the important concepts in IoT and background in aquaculture.

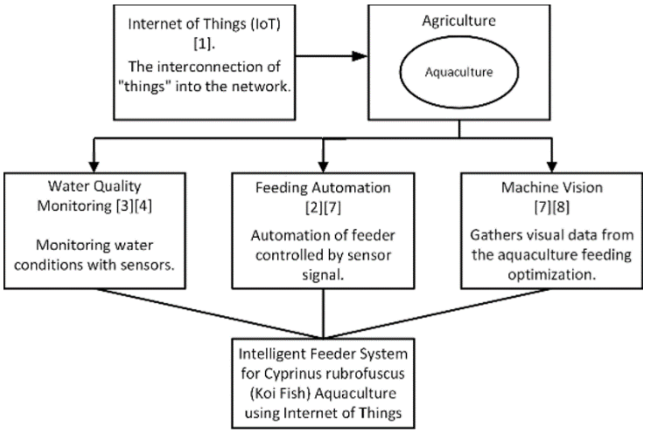

Fig. 1. Theoretical framework of the study

B. Conceptual Framework

Figure 2 showcase the conceptual framework of the study with the basic premise to output the intended values from the sensor and actuator into a graphical user interface (GUI), typically for mobile applications.

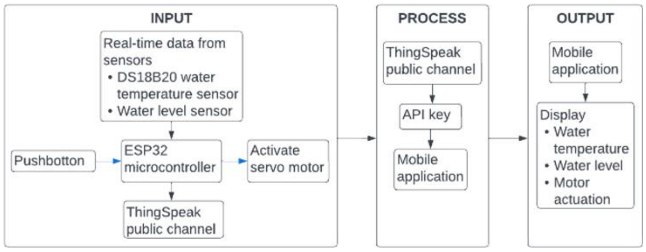

Fig. 2. Conceptual framework of the study

This uses the ThingSpeak application programming interface (API).

III. Design Methodology

The proposed system block diagram for creating the intelligent feeder system is shown in Figure 3.

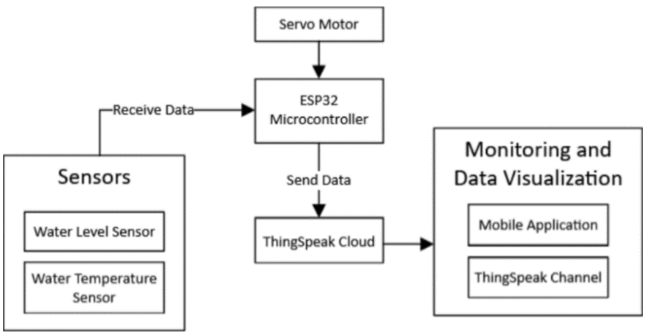

Fig. 3. System block diagram

Here, the connections of the system are visualized. The sensors responsible for detecting water quality are connected to the ESP32 microconpatroller. The two sensors selected are the water level sensor, and the water temperature sensor. As the sensors gather data, the ESP32 will receive incoming data from the sensors. The ESP32 was set up to connect to a WiFi network to connect to the internet. Once connection is established, the ESP32 will send the sensor data to the ThingSpeak cloud where the data will now be stored. By developing a mobile application, the user will be able to check the water level and water temperature condition in an interface that is suited for mobile devices. The ThingSpeak channel was also used to visualize the data from the ThingSpeak cloud. The system setup along with the components is shown in Figure 4.

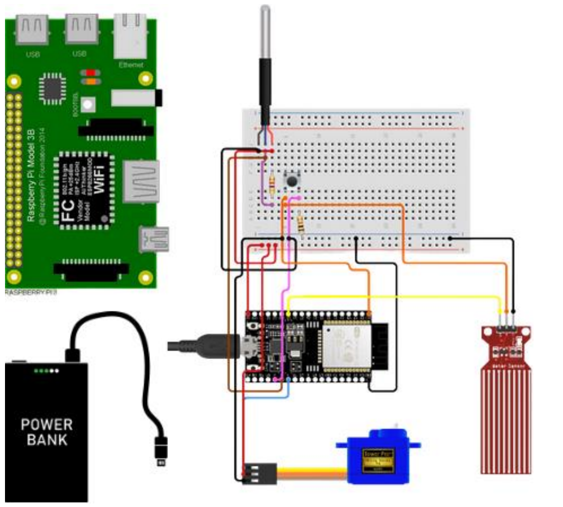

Fig. 4. Conceptual framework of the study

Here, the detailed connections for the system can be seen. Starting with the sensors, the water level sensor's signal pin is connected to an analog pin of the ESP32. The DS18B20 water temperature sensor is connected to a 10k-Ω resistor and connects to a signal pin in the ESP32 because the ESP32 is responsible for sending the data to the cloud. In this setup, all ground pins of the components are connected to a common ground which is from the RPi.

In this design, the RPi acts as a centralized power supply for the sensors and the servo motor. Both the sensors' supply pins are connected to the RPi. Similarly, the SG90 micro-servo motor which is responsible for opening the feeding container for the fish is connected to an analog pin in the ESP32 and is connected to power from RPi and to the common ground. A pushbutton was connected to the ESP32 to act as a proxy signal to control the movement of the servo motor. The pushbutton signal emulates the automatic signal that will trigger the movement of the servo motor. Finally, a power bank is used to supply power for both the RPi and the ESP32.

The project implementation was divided into 5 sections. First, the hardware was initialized. Necessary connections as described earlier were performed. A public channel within ThingSpeak with 4 different fields was created. The 4 fields are for water temperature data, water level sensor, motor actuator based on the units the pointer moved, and viewing the channel location. The API key from the ThingSpeak public channel is used to collect the data from the sensors and display them on a mobile application. This API key is used to program the ESP32 in the Arduino IDE such that the ESP32 can connect to the cloud.

IV. Results and Discussion

Shown in Figure 5 is the overall setup of the automatic feeder system that the proponents made.

Fig. 5. Setup of the automated feeder system

This is made out of cardboard corrugated box material as housing. The size of the housing was made in consideration of the largest components that will occupy space which are the powerbank and the breadboard side-by-side. Adjacent to the main housing, it evinced the housing for the fish food pellet. It is made from a corrugated cardboard box with a masking table to provide a simple opening and closing of the pellet. It will then be sealed and the servo motor will have another cardboard box attachment that will act as a blocker of the opening of the fish pellet housing. The fish food pellet is suitable for the target fish which is koi fish.

The resulting data from the different sensor values manipulated with corresponding units appropriate to the message they want to convey is shown in Figure 6.

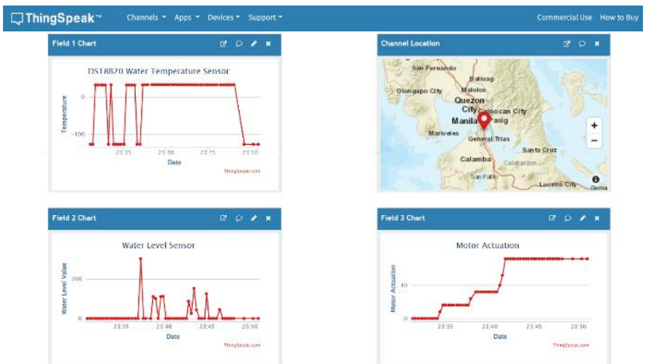

Fig. 6. Output ThingSpeak public channel for feeder system

Particularly, the first field was able to relay the common temperature value within the tank ranges from 33 to 37ºC based upon the testing that was made for the sensor and the field chart shown.

Shown in Figure 7 is the produced GUI from MIT App Inventor as proof of the feeder system's functionality showcasing how the water temperature at the time of demonstration is around 32.37ºC, the water level is at 80% near overflow and the motor has a recorded history of 2 actuations made throughout its run.

Fig. 7. Developed GUI for feeder system

The motor actuation acts as recording of how many times this the system has conducted feeding.

V. Conclusion and Recommendations

IoT technologies find many applications in the modern industry, including agriculture. Due to its powerful capabilities for remote monitoring and control, IoT is applied in optimizing environment conditions of aquaculture, where optimal environmental conditions are crucial to growth and health of aquatic organisms. In this study, an intelligent feeder system was developed for the aquaculture of koi fish. The water condition of the fish cages was monitored using a water temperature sensor, and water level sensor. The opening of the feeding container is controlled by a servo motor, which automatically activates responding to the pushbutton signal. The sensors and servo motor connect to a centralized power supply in the form of RPi, and the entire system including the ESP32 is supplied by a power bank. Sensors and the servo motor were connected to the ESP32, and the data was sent to the ThingSpeak cloud to a dedicated public channel. Sensor values and motor actuation were displayed and monitored in a developed mobile application app.

Further improvements can be introduced to the system, especially to the feeding mechanism. It is recommended that a real-time clock (RTC) module is integrated with the servo motor, such that the actuation can be set to a designated time or day. In the current design, the system emulates the delay of the RTC in the program itself using the signal from the pushbutton. Therefore, to fully realize the automation and customization of the system, an RTC module is a necessary component. This also enhanced the applicability of the feeding system to other aquaculture feeding systems since it allows the user to program specific feeding time required for a target organism. An integrated webcam that can be accessed remotely is also another useful addition to the system. The webcam creates another avenue for surveillance of the fish and their behavior which could be used as information to predict more accurate feeding time. It is also possible to make upgrades by integrating computer vision.

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