IoT Solution for Intelligent Pond Monitoring

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Abstract. Channa striata or the striped snakehead fish is one of snakehead fish species which inhabits all types of freshwater bodies distributed across Asian countries. Because this fish is known to have higher albumin fraction (64.61%) of protein and other economic values, domestication, and cultivation of this fish has been done in many Asian countries such as Indonesia, China, Malaysia, Thailand, Bangladesh, and India. Environmental factors such as temperature, water pH, dissolved oxygen, total dissolved solids, and turbidity are important parameters must be considered inbreeding and growing this type of fish. The aim of this paper is to propose an IoT solution to automatically monitor these environmental factors. It is designed with affordable and open-source electrical components to provide a cost-efficient solution for farmers. Five sensors are used to measure each parameter. A web application prototype is also presented as a companion application for the users to get useful information from the IoT device. It is developed using a Python framework. By accessing this web application, the users can immediately detect any abnormal conditions of the pond.

1. Introduction
The striped snakehead fish (Channa striata Bloch) is a carnivorous fish which inhabits all types of freshwater bodies, including swamps, lakes, rivers, and rice fields, distributed across Asian countries from Pakistan and India to Southeast Asia and Southern China [1]. Due to its rapid growth and tolerance to high stocking density, the fish has great economic values [2, 3]. Domestication and cultivation of the fish have been done in many Asian countries such as Indonesia, China, Malaysia, Thailand, Bangladesh, and India [4]. Moreover, medicinal values of the fish, for example having wound healing properties and reducing postoperative pain, also have contributed to its growing market demand [5, 6]. In addition, the fish is also known to have higher albumin fraction (64.61%) of protein, compared to other animal protein sources, and has been an extensive subject to clinical research [7].
The striped snakehead is a stenohaline fish, an organism that can tolerate only slight changes in salinity. Referring to laboratory observations made in Mandiangin Freshwater Aquaculture Fisheries Center [8], it shows that a level of water salinity of 12 g/L is considered as the upper lethal limit for the survival of the fish. The study also reveals that even at a salinity of 10 g/L, the fish growth and the chance of survival can be critically affected. It is suggested that the striped snakehead is well adapted in an environment with the level of salinity up to 5 g/L. Moreover, the temperature variation to attain ideal condition for the spawning stage of the snakehead fish is ranged from 27.9 to 31.2 °C. The rearing process needs a slightly warmer temperature range, which is 27.8 to 32.5 °C. Afterwards, when the maturation takes place, the optimal temperature range is found to be 26.8 to 32.1 °C. On the other hand, the optimal pH levels for the fish living in a man-made ecosystem can be summarized in each process, i.e spawning: 5.3-7.0, rearing: 4.0-6.3 and maturing: 4.4-6.1. Then the adequate dissolved oxygen (DO) concentration of 0.6-8.7 mg/L, 0.5-7.4 mg/L, and 0.2-8.6 mg/L are needed for the spawning, the rearing, and the maturing stage, respectively. The summary of the ideal condition for striped snakehead fish and fish cultivation farm are listed in Table 1 and Table 2.

A study measured the association between turbidity and the variety of fauna to find if turbidity affects the freshwater fish wellbeing [9]. The measurement took place at 202 places in the rivers in the United States. The data shows that places with lower turbidity have a wider variety of species and places with higher turbidity or muddy places are less diverse. A precise conclusion cannot be drawn from these data because few places still have good fish populations despite the muddy condition. However, the author suggests that a certain level of turbidity may decrease fishery quality.

The dissolved materials in the water of the fish cultivation farm are also critical to the fish survivorship and development [10]. Most of the dissolved materials in water are bicarbonate, sodium, sulfate, and chloride; that can affect gill and kidney function of the fish. A collaborative study between Nevada Department of Wildlife (NDOW) and the United States Fish and Wildlife Service (USFWS), found a decline in daily catch since 1992 to 2007 concurrent with increases in Total Dissolved Solids (TDS) in the area [10].

Table 1. The ideal condition for a striped snakehead fish [8].

| Environmental parameters | Spawning stage | Rearing stage | Maturation stage |
|--------------------------|----------------|---------------|-----------------|
| Salinity                 | 5 - 9 g/L      | 5 - 9 g/L     | 5 - 9 g/L       |
| Temperature              | 27.9 - 31.2 C  | 27.8 - 32.5 C | 26.8 - 32.1 C   |
| pH                       | 5.3 - 7.0      | 4.0 - 6.3     | 4.4 - 6.1       |
| DO                       | 0.6 - 8.7 mg/L | 0.5 - 7.4 mg/L| 0.2 - 8.6 mg/L  |

Table 2. Ideal condition for general fish cultivation farm [9], [10].

| Environmental parameters | Ideal condition                                                                 |
|--------------------------|----------------------------------------------------------------------------------|
| Turbidity                | The lower the turbidity, the higher the fish quality                              |
| TDS                      | High TDS level will affect fish survivorship and development                      |

With the increasing economic importance of modern aquaculture industry, more efficient management of water quality becomes an important key in determining the stability of fish production. Frequent monitoring and measurement of water environmental parameters such as oxygen level, temperature, and pH, is crucial to maintain suitable conditions and avoid risky situations that can have detrimental effects on fishes [11]. However, continuous manual monitoring and measuring the water quality, for example in aquaculture ponds, may be costly, tedious and time-consuming tasks. It, therefore, encourages the adaptation of smart Internet of Things (IoT) based automation for the monitoring of fish ponds.

Recent advances in information and automation technologies are speeding up the progress of IoT system that utilizes interconnectivity devices to collect data from sensing devices and then share that
data across the internet where it can be analyzed for various decision-making purposes [12, 13]. The main objective in this direction aims to create a monitoring scheme that allows the IoT system to automate the checking processes in a faster way. Basically, a set of sensors are placed in the ponds to measure critical parameters such as oxygen level, pH, temperature, and total dissolved solids (TDS). The obtained real-time information will be transmitted to the server from remote locations, which eventually will notify fish farmers for accurate decision making. Real-time monitoring is needed to anticipate potential risks for organisms due to rapid changes of parameters that determine the water quality [13].

In this paper, we aim to propose a smart IoT pond for monitoring the parameters of water quality that is targeted specifically towards the cultivation of the striped snakehead. The system is composed of sensors that measure the vital parameters of the water quality: dissolved oxygen, temperature, pH, total dissolved solids (TDS), and turbidity. We provide an attempt to deploy such an intelligent monitoring system to improve efficiency and potentially boost economic benefits of the striped snakehead fishery. By using the sensors, this solution can also be considered as an Internet of Things (IoT), which is being massively deployed in developing countries[14, 15].

2. Related Works
Several developments in IoT based monitoring for aquaculture are currently underway with applications in various aspects of the monitoring system. In line with tremendous research efforts in this area, European Commission in 2017 H2020 innovation action call coined a term “Aquaculture 4.0” to refer to smart aquaculture integrated with IoT system with active research projects [16]. The projects focus on 1) Development of high performance and low-cost sensors: PROTEUS project is developing carbon nanotubes based chemical sensors 2) Affordable and easy-to-deploy technology: WAZIUP project in Ghana 3) Smart and friendly environmental systems for aquaculture: IMPAQQT project [17-19].

The authors in [20] have designed and implemented a prototype of a distributed monitoring system based on wireless sensor network (WSN) and on IoT to monitoring water quality in ponds. The proposed system is claimed to be low cost, low power consumption, portable, versatile, and accurate. In [21], an IoT based automated system comprises of pond controller with various sensors for monitoring equipped with an integrated CCTV that can record activities around the pond. Moreover, authors in [22] have proposed the utilization of Wivity modem into the IoT monitoring system that supports various connectivity through WiFi, GSM, satellite communication, or LoRaWAN, allowing real-time monitoring in a remote area with limited cellular connection or a certain type of internet connections. On the other hand, several papers [23-25] detailed more specific IoT monitoring systems for various aquatic organisms such as shrimp, catfish, crab.

3. Methods
This smart pond is designed to accommodate the required environments for snakehead fish to grow well. The proposed solution can be divided into two parts, the IoT solution and the web application as the user interface system.

3.1 IoT Solution
The ideal condition for snakehead fish can be achieved by maintaining all parameters as previously described in Table 1 and Table 2. However, due to the limitation of the current affordable sensor for salinity, we excluded this parameter in our proposed solution. This proposed solution is aimed to give a cost-efficient solution for fish farmers, so we try to build inexpensive IoT device.

As the main controller which controls all other components, an open-source IoT platform called NodeMcu is used [26]. It is a platform to build an IoT solution using the Lua programming language [27]. A WIFI module is integrated into this microcontroller to allow internet connectivity to push the data into the server. Since it only provides one Analog-Digital Converter (ADC) port to connect the sensor, an additional ADC module is used to add more sensors connectivity to the microcontroller. A
logic converter is used as a bridge between the microcontroller and ADC module which has a function to adjust the voltage between these two arts. In total there are four sensors embedded in this solution which represent each parameter we monitored. The total list of all electrical components and the architecture can be seen in Table 3 and Figure 1 respectively.

Table 3. Electrical components list.

| Components                | Function                                                                 |
|---------------------------|--------------------------------------------------------------------------|
| NodeMcuESP8266            | Microcontroller with WIFI ESP8266 module                                 |
| ADC Ads1115               | Analog-Digital Converter (ADC) with I2C communication                    |
| Logic converter           | Safely steps down 5V signals to 3.3V AND steps up 3.3V to 5V at the same time |
| Dissolved oxygen and temperature sensor | Measured dissolved oxygen levels and temperature                        |
| pH sensor                 | Measure water pH level                                                   |
| Turbidity sensor          | Measure the amount of light that is scattered by the suspended solids in water |
| TDS sensor                | Indicates the total dissolved solids of a solution, i.e. the concentration of dissolved solid particles |
| DC-DC converter           | An electronic circuit or electromechanical device that converts a source of direct current from one voltage level to another. |
| Power Supply              | Provide electrical power for the device                                 |

Figure 1. Proposed IoT solution architecture.

3.2 Web Application
To provide a user interface system for the users to monitor the actual condition of the ponds, a web application prototype is proposed. This web application will provide a report to users regarding the current state of each pond based on the targeted parameters. By looking at this web application, the users will easily catch any abnormal condition of the ponds and can immediately plan an action to address the problem. This web application is developed using Python web development framework [28] and connected to a MySQL database.

4. Result and Discussion
4.1 IoT Solution
The proposed IoT architecture was successfully developed into a working prototype. All the electrical components were assembled on a Printed Circuit Boards (PCB) as illustrated in Figure 2. Eventually, this solution will be placed at a specific place near the pond so it is resistant against water, dust, and
any other particles need to be considered in the real implementation. The idea is to keep the main microcontroller and other parts out of the pond water. Only the sensors’ probe will be placed inside the water to measure the quality of the water.

![IoT solution prototype](image)

**Figure 2.** IoT solution prototype.

An example illustration of this proposed IoT solution implementation can be seen in Figure 3. In Figure 3, the main controller is placed on the pole beside the pond to avoid any direct water contact that can damage the electrical parts. It is connected to the power supply which comes from the solar panel installed above it. All the sensor probes are installed in the pond so it can directly measure environmental parameters of the water.

![Illustration of solution implementation](image)

**Figure 3.** Illustration of solution implementation.

### 4.2 Web Application

There are four main features offered by the proposed web application as a companion app of our proposed IoT solution. The first main feature is the dashboard to shows the current measurement of the pond. The users also can see more detailed information on each pond. To adjust the ideal condition of the pond, there is a feature that allows users to adjust the threshold of the parameter which used to detect the abnormal condition of the pond. Figure 4 depicts the full use case diagram of this proposed web application.
The users need to login to the web application in order to access all the features. There is no signup feature to limit only specific persons can be registered to the system by administrators. The login page can be seen in Figure 5.

Once the users successfully login to the system, they will be redirected to the dashboard page. This page displays all current condition of each pond monitored by the IoT devices. The data is presented in a table style with all the parameters as columns and one additional ID column to differentiate each pond. A more detailed view of each pond can be accessed by clicking the hyperlink in each row. It shows information in a bar graph for each parameter with the current value of the measurement. To detect an abnormal condition of a pond, there is a red highlight on the abnormal data as can be seen in Figure 6. In the more detailed page, the bar graph for the abnormal data is also highlighted with red color, while other normal data is highlighted in green color as illustrated in Figure 7. This simple presentation will help the users to easily catch any abnormal condition immediately.
To provide a flexibility monitoring system, this application allows the users to manually adjust the ideal condition which will define the abnormality on the monitoring process. The ideal condition thresholds can be altered by accessing the ideal condition page as depicted in Figure 8. Additionally, the users also can add more devices to the application when more devices are applied in new ponds. The page to add new device is illustrated in Figure 9.
5. Conclusion

In this paper, an IoT solution is proposed to automatically monitor the environmental condition of the pond for the striped snakehead fish domestication. It is developed mainly using open-source electrical components such as NodeMcuESP8266 microcontroller and some Adafruit sensors. The prototype has
been developed based on the proposed architecture in a standard PCB. This IoT solution can measure five vital environmental parameters in breeding the striped snakehead fish, namely temperature, water pH, dissolved oxygen, total dissolved solids, and turbidity. To help the farmers in monitoring the current condition of the pond, a web application prototype is also developed as a complementary application. By accessing this app, the users can easily spot any abnormal conditions of the pond and can immediately take actions to solve the problem. These solutions will help the farmers in doing fish domestication in an effective and efficient way. This solution will be implemented in a real-life environment to validate its reliability and usefulness. Other future works including integrating push notification into this solution can be considered to enhance the user experience.

6. References

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