ISSN 2278-3091
Volume 9, No.4, July – August 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse172942020.pdf
https://doi.org/10.30534/ijatcse/2020/172942020

Fuzz-Fish: A Design and Implementation of Fuzzy Fishpond Aquaculture Control Sensing System

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ABSTRACT

Aquaculture has been one of the world's fastest growing food-producing industries and its survival is important. Different indications of factors that can affect the behavior of the fish must be controlled. Monitoring the water quality and feeding schedules are the major elements that affect the growth of fish. Therefore, monitoring the amount of water and ensuring that feed is supplied correctly is necessary for farm owners to produce a good number of harvests. Fish farmers typically rely on irrigation and rain, which causes problems, particularly during the summer, and "sabog" of feeds is the practice of fish feeding. These methods are challenging and time-consuming. Because of these, the development of automatic water level monitoring with a reflexive feeding system has been proposed. This will automatically drain/refill water if needed and release the exact amount of feeds depending on the number of fish. The system utilizes different sensors, materials, and components for data gathering. An aquarium type of pond was used for ease of testing. In managing the method, Fuzzy logic was applied based on the specified criteria, the nature of knowledge-based principles, the inference mechanism and defuzzification. The results show that the system performed a 92% success rate. This means that the system is working effectively in water level monitoring and reflexive fish feeding.

Key words : Aquaculture, Feeder, Fuzzy Logic, Miconcontroller, Reflexive, Water Level Controller.

1. INTRODUCTION

Aquaculture has been one of the world's fastest-growing food-producing sectors and its sustainability is essential. Fish farms may be built both inland and at sea. Sea facilities consist of cages where fish are held apart from other animals, whereas inland systems were placed in tanks where temperatures were monitored and had an effect on fish production. Different indications of factors that can affect the behavior of the fish must be controlled [1]. Monitoring the water quality and feeding schedules are the major elements that affect the growth of fish [2]-[3].

Feed and feeding are important to development and manufacturing. The management is one of the major challenges for the growth, survivability and sustainability of aquaculture. Adjustment of food supplies to ensure the sustainability of fish is important to fish owners, whether as pets or as aquaculture. One feature that affects a feeder is a time management system that functions as the central part of a feeder. Workers often face difficulties in doing the feedings simultaneously during unpredictable incidents, especially while rainy. If this practice continues, the only consequence is not just the pellet stopping at the bottom of the pond as waste more easily or causing water to pollute, but the most important issue is the unfed fish [4]. Adequate feeding increases the growth rate of agricultural plants and decreases the emissions of food waste and energy. Monitoring of physicochemical parameters, such as dissolved oxygen, pH , salinity, and temperature, must be calculated in real time and include evidence and carry out corrective steps and preserve optimum output conditions. Furthermore, a crucial element is the dissolved oxygen. Depletion decreases stock development and appetite; low rates may trigger death; pH and salinity must remain within a particular cultivation range; and temperature affects output, feeding performance, and reproduction [5].

There are various feeders, and feed consumption monitoring devices were studied to minimize the challenges in fish feeding. According to [6] the use of a hydroacoustic sensor to detect pellets in sections of 2.5 m inside cages immersed in the sea was proposed, in which feeding availability depended on food. Also tested was the installation of a device focused on fish presence sensors installed at various tank heights and a feed detection sensor placed in the drainage tubes. A light-dependent resistor (LDR) is the foundation for the fish presence sensor [1]. Moreover, many studies were conducted to minimize the challenges experienced by the farm owner and its worker. Robotic System based on SONAR and ultrasonic sensor used in a robotic boat that detects the fish in the water on which it is floating has been proposed. This

Robotic System was use for automation of water quality monitoring and feeding in aquaculture shadehouse [7].

Many studies were also conducted to minimize the challenges in pond water level and quality monitoring. Recent works used different sensors integrated with the Internet of Things (IoT) and machine learning algorithms in water real-time monitoring. Fuzzy logic approaches have been used to improve the evaluation of water quality. In fuzzy logic, the concept of fuzzy sets, the design of knowledge-based rules, the inference process, and the defuzzification process were carried out [8]. The design and implementation of a filter pump controller were used to monitor the quality of water in a fish aquarium based on Fuzzy Logic. The fuzzy logic in the controller was used to provide the power of the filter pump operation based on the details about the turbidity degree of water obtained from the photodiode sensor and the acidity of the pH sensor water gathered [9]. Fuzzy logic was also used as a dynamic feed technique combined with mathematical functions (MF). The goal is to develop feeding strategies for shrimp farming based on water quality parameters. The result shows that the parameter that most of the time influences the feed rate (74 %) while the temperature still influences the feed rate but lower (26%)[10]. The indoor shrimp cultivation control system based on fuzzy logic has also been introduced for dissolved oxygen control. The fuzzy logic controller is based on a microcontroller, which is combined with many auxiliary units [11]. Moreover, other applications are in automatic irrigation system [12] and rice straw decomposistion system [13].

Monitoring the amount of water and ensuring that feed is supplied correctly is necessary for farm owners to produce a good number of harvests. Monitoring the water level regulates the volume of water at the normal level, avoiding waste and loss of quantity any time the water leaks in the pond or when the water evaporates mainly during the summer season and when the water overflows during the rainy season. The conventional method used to monitor the water level is the installation of marks on the pond and visual inspection. Fish farmers typically rely on irrigation and rain, which causes problems, particularly during the summer. Even today, most fish farmers are using a manual feeding system or a "sabog" process. This process is more difficult for the farmers because it needs additional laborers to handle the jobs in aquaculture like maintaining, cleaning, dispensing the excess food stored in the tank, and filling the feeder. It takes much time, and the cost of labor is too more. Like this, there are two major problems faced by the fish farmers today: insufficient oxygen (O2), the other one is growth monitoring, and how to feed fish at the right time with less manpower involvement [14] . High water temperature is one of the major causes of the declining production of fish, such as tilapia in the Philippines. Having more stable in temperature, salinity, and dissolved oxygen to increase the growth of fish is needed for the growth of tilapia, considering the seasons [15]. The use of different market readily available tools and devices is a great help for fish production. However, most of these are high priced tools and devices and require the expert for calibration and installation. This just added to the challenge of the farm owners, especially for those who are just renting fish farmland.

Because of these challenges, this leads to the proposal of this study. The objective of this study is to design and implement fishpond aquaculture monitoring of water level integrated with a feeding system that will automatically release the exact amount of feeds depending on the number of fish. The system utilizes different sensors, materials, and components for data gathering. Because the traditional pond depends on the water irrigation and rain availability, the proposed system used an aquarium type of pond for ease of testing. The calculation was made for the prototype size and water volume based on the actual interview made from the farm owner in Laguna, Philippines. Water level monitoring will be done based on the data from the water level sensor. This will keep the pond water at a normal level to keep plenty of room for fishes to move and exercise to evade fatality. On the other hand, the timing sequence is integrated to automate the method of fish feeding “sabog” according to the age and number of fish in the pond. This will ease the imbalanced time interval for feeding, resulting in an uneven weight of fishes on their ideal weight. Fuzzy logic was used in controlling the system based on the set parameters, design of knowledge-based rules, the inference process, and the defuzzification.

2. TECHNICAL DESIGN

2.1 System Architecture

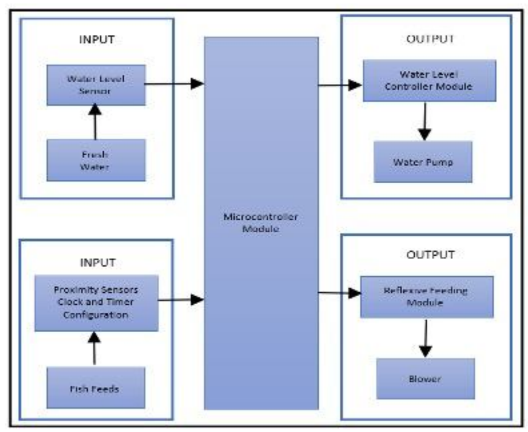

Figure 1: Architecture of Fishpond Aquaculture Control Sensing System

The system is capable of two main functions as shown in Figure 1: automatic monitoring of the water level and reflexive feeding based on the set time and quantity of fish feed. Two microcontrollers were used to PIC16F84A and PIC16F877A for the control system as shown in Figure 2.

2.2.1 Water Level Controller Module

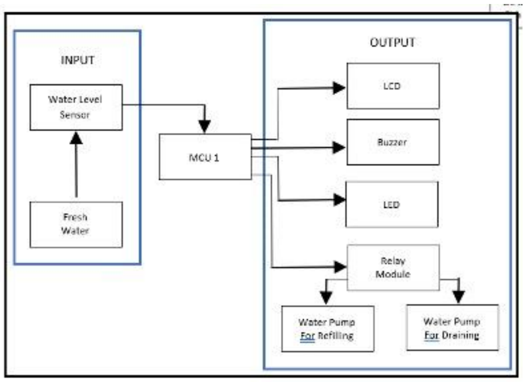

Figure 2: System Components of Automatic Water Level Monitoring Module

Three sensors were attached in front of the steel frame fishpond prototype. The water level sensor is set to monitor three (3) levels: critically low, normal, and critically high. The critically high level means it is a seriously high amount of the required water level on the pond, critically low level means it is a seriously small amount of the required water level on the pond, and the normal level means it is the standard water level requirement on the pond. If the water level is critically high or critically low, it will trigger a signal to automatically drain or refill water until it reaches the normal water level in the aquarium pond.

The amount of water is calculated using *L x W x H = Volume* of the prototype results to *4.9 x 3.28 x 2 = 32.144 cu. ft.* The level of *2 cu. ft.* water normal level was computed based on the size of the prototype. The volume of water used is 240.453818 gallons. The basis of the prototype was based on the fish farm owner in Laguna.

2.2.2 Reflexive Feeding Module

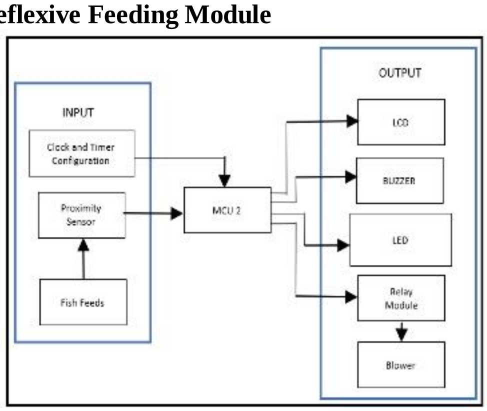

Figure 3: System Components of Reflexive Feeding Module

The feeding system as shown in Figure 3 is capable of automatically assigning feeds to the pond using the timing sequence for the proper distribution of feeds in a timely manner. The reflexive feeding system was integrated with feed container monitoring to continuously provide the food needed and ensure that all fish have the possibility of eating the food on time to maximize the fish growth.

The aquarium type pond has a Total Volume of 240.453818 gallons, with the use of a thumb method of ¼ lb/gal of fish, this can get the total weight, a total number of fishes in a pond and the Daily Feed Ration (DFR).

Total weight of fishes (Twf) in a pond:
Twf = ¼ lb/gal (240 gal)
Twf = 60lb ➔ 27kg

Total number of fishes (Tf) in a pond for 150g finisher:
250g ➔ 0.55116lb
0.55116lb/gal (Tf) = 60lb
Tf = 108.86 ➔ 109pcs

For 109pcs of fishes as maximum, get the average body weight:
Average Body Weight (ABW)
ABW (g) = total weight of fish randomly sampled / # of fish sampled
ABW = 1306g / 5pcs = 261.2g

Amount of feeds to be allocated daily, aquacultures called it as the Daily Feed Ration.
Daily Feed Ration (DFR)
DFR is the amount of feeds given daily = ABW * total number of stocks * feeding rate * survival rate
DFR = 261.2g * 109pcs * 2% * 95%
DFR = 540.53g ➔ 0.54kg a day or 270g ➔ 0.27kg twice a day

2.3 Materials and Components

A. Microcontroller Module

PIC MCUs were used to control the overall functionally of the system. This provides the signal on what the module will function according to the collected data.

B. Water Level Sensor

It was used to measure the current level of water inside the aquarium pond. This sensor is directly connected to the MCU that will send a signal to the water pump to function accordingly.

C. *Water Level Indicator* (*Pond Ruler*)

A tool used to determine the water level made of a fiberglass material where wires are attached to it as a sensor

D. Relay and Water Pump

The device that automatically controls the circulation of water in the aquarium pond for refilling and draining based on the water level sensor readings.

E. Clock and Timer Configuration Module

This serves as the feed controller that regulates the number of feeds being released in the feed container. A feed container and feeding funnel are attached to it made of fiberglass material and plastic jug that fixedly measured and able to hold the exact amount of feeds to be released on the pond.

F. Proximity Sensor

The component used to determine the level of feed in the feed store. This will trigger the alarm once it reached a low level.

G. Liquid Crystal Display (LCD)

The component used to visualize the status of the water level monitoring and reflexive feeder. This is also used to demonstrate the given inputs to the system.

H. DC Motor

Use used to trigger the movement of the feed container to clear the lid and prepare the feeds to be release.

I. Gate Valves

It is used to control the water releasing from the aquarium type pond.

J. Feed Container

It was made of fiberglass material fixedly measured, which can hold the exact amount of feeds to be released on the pond. It is integrated with a feeding funnel made of tin material as shown in Figure 4.

Figure 4: LCD module (left) and Water Level Controller and Reflexive Feeder (right) Component Testing

3. FUZZY RULE-BASED SYSTEM DESIGN AND IMPLEMENTATION

There are 3 steps in fuzzy logic implementation: Fuzzification, Development of Rule Base, Defuzzification for automatic water level controller, and reflexive feeder. Shown in Figure 5 is the elements in the Fuzzy Rule-based Control System. The following sections below deal with each function separately.

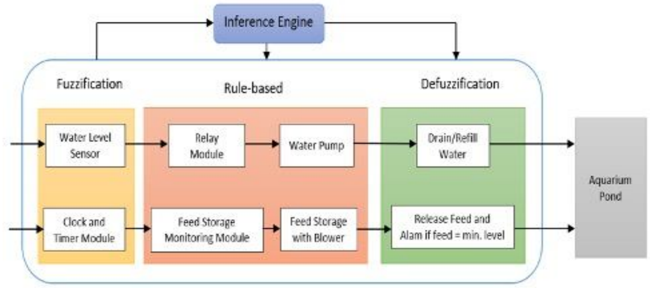

Figure 5: Block Diagram of Fuzzy Fishpond Aquaculture Control Sensing System

2.4.1 Fuzzy Rule-Based Implementation for Water Level Controller

A. Fuzzification

Table 1: Variable and Ranges For Automatic Water Level Controller

Water Level Reading	Fuzzy Set	Action to be Performed	Action to be Performed by the Water Pump
0 – 1.9 cu. ft.	CL = Critically Low	Trigger Refill Pump	Refill Water (Closed Valve)
2 cu. ft.	NL= Normal	Continue Reading	No Action (Closed Valve)
2.1 – 3.5 cu. ft.	CH = Critically High	Trigger Drain Pump	Drain Water (Open Valve)

B. Fuzzy Rule-based

RULE 1: IF Water Level Reading IS >= 1 ft. AND Water Level Reading IS <= 1.9 ft THEN Trigger to REFILL PUMP

RULE 2: IF Water Level Reading IS >= 2 ft AND Water Level Reading IS <= 2.9 ft THEN CONTINUE READING

RULE 3: IF Water Level Reading IS >= 2.1 ft AND Water Level Reading IS <= 5 ft. THEN Trigger to DRAIN PUMP

C. Defuzzification

Table 2: Functionality of the Water Pump

Water Level Reading	Drain Water Pump	Refill Water Pump
0 – 1.9 cu. ft.	CLOSED	OPEN
2 cu. ft.	CLOSED	CLOSED
2.1 – 5 cu. ft.	OPEN	CLOSED

3.4.2 Fuzzy Rule-Based Implementation for Reflexive Feeder

A. Fuzzification

Table 3: Variable and Ranges of the Reflexive Feeder

Set Parameters (Time)	Fuzzy Set		Action to be Performed
	Feeder Storage (FS)	Lid	
7: 00 AM	LL = Low Level	OPEN	TRIGGER
	NL = Normal Level	OPEN	TRIGGER
	CL = Critical Level	CLOSED	ALARM
5:00 PM	LL = Low Level	OPEN	TRIGGER
	NL = Normal Level	OPEN	TRIGGER
	CL = Critical Level	OPEN	ALARM

B. Fuzzy Rule-based

RULE 1: IF Time IS Equal to 7:00 AM AND FS IS NL THEN Triggered REFLEXIVE FEEDER

RULE 2: IF Time IS Equal to 5:00 PM AND FS IS NL THEN Triggered REFLEXIVE FEEDER

RULE 3: IF Time IS Equal to 7:00 AM AND FS IS LL THEN triggered REFLEXIVE FEEDER

RULE 4: IF Time IS Equal to 5:00 PM AND FS IS LL THEN triggered REFLEXIVE FEEDER

RULE 5: IF Time IS Equal to 7:00 AM AND FS IS CL THEN triggered ALARM

RULE 6: IF Time IS Equal to 5:00 PM AND FS IS CL THEN triggered ALARM

RULE 7: IF FS IS Triggered AND FS IS LL THEN Triggered ALARM (5 seconds)

RULE 8: IF FS IS Triggered AND FS IS CL THEN Triggered ALARM (15 seconds)

C. Defuzzification

Table 4: Functionality of the Reflexive Feeder System

Time (Hour)	Fuzzy Set	Alarm	Reflexive Feeder	Action
7: 00 AM	LL = Low Level	ON	TRIGGER	Release Feeds
	NL = Normal Level	OFF	TRIGGER	Release Feeds
	CL = Critical Level	ON	LOCKED	Alarm
5: 00 PM	LL = Low Level	ON	TRIGGER	Release Feeds
	NL = Normal Level	OFF	TRIGGER	Release Feeds
	CL = Critical Level	ON	LOCKED	Alarm

4. TESTING AND RESULTS

Testing is done within 2 days. Two types of tests are carried out, namely a without disturbance and with disturbance. Five (5) number of experiments were carried out on the first day and five (5) on the second day on the water level and ten (10) on the reflexive feeder as shown in Tables 1, 2, 3, and 4. The testing of components was first conducted to ensure its functionality. Table 5 shows the summary of the experiments performed.

Table 5: Test Results of the Automatic Water Level Controller System

# Trials	Water Level Readings	Remarks	Action Performed by the Water Pump	Results
1	1.5 cu. ft.	CL = Critically Low	Triggered Refill Pump	Successful
2	2 cu. ft.	NL= Normal	Continue Reading	Successful
3	2.5 cu. ft.	CH = Critically High	Triggered Drain Pump	Successful
4	2 cu. ft.	NL= Normal	Triggered Drain Pump	Unsuccessful
5	1.0	CL = Critically Low	Triggered Refill Pump	Successful
6	2 cu. ft.	NL= Normal	Continue Reading	Successful
7	1.7 cu. ft.	CL = Critically Low	Triggered Refill Pump	Successful
8	3.1 cu. ft.	CH = Critically High	Triggered Drain Pump	Successful
9	2.9 cu. ft.	CH = Critically High	Triggerd Drain Pump	Successful
10	2 cu. ft.	NL= Normal	Continue Reading	Successful

The clock and timer were manually configured to test the reflexive feeder system. Using the LCD, the set time, and measured status of feeding storage was easily checked if the input configuration was correct. Table 6 shows the result of testing conducted when the system does the expected output needed.

Table 6: Test Results of the Reflexive Feeder System

# Trails	Time	Feed Storage Condition and LID Status	Action Performed by the Reflexive Feeder	Alarm	Results
1	6:55 AM	NL	Untriggered	OFF	Successful
2	5:00 PM	NL	Triggered	OFF	Successful
3	7:00 PM	CL	Untriggered	ON	Successful
4	7:00 AM	NL	Triggered	OFF	Successful
5	1:24 AM	LL	Untriggered	OFF	Unsuccessful

6	6:21 PM	NL	Untriggered	OFF	Successful
7	6:67 AM	LL	Untriggered	OFF	Successful
8	5:00 PM	NL	Triggered	OFF	Successful
9	12:00 PM	CL	Untriggered	ON	Successful
10	9:14 PM	CL	Untriggered	ON	Successful
11	7:00 PM	CL	Untriggered	ON	Successful
12	7:00 AM	NL	Triggered	OFF	Successful
13	5:00 PM	NL	Triggered	OFF	Successful
14	5:00 PM	CL	Untriggered	ON	Successful
15	10:10 PM	LL	Untriggered	OFF	Successful

5. CONCLUSION

The results demonstrate the overall functionally of the system based on the set fuzzy logic conditions. Shown in table 5 and 6 how the water level controller and reflexive feeder responded based on the inputs. The application of the fuzzy logic method on the system optimize the water level monitoring and the releasing of fish feeds. The test results shows that the system performed a 92% success rate. This means that the system is working effectively in water level monitoring and reflexive fish feeding.

ACKNOWLEDGEMENT

The authors would like to thank the owner of the Laguna fish farm for giving time to the data collected. No name and fish farm information is stated as requested by the owner.

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