Design of Smart Biofloc for Real-Time Water Quality Management System

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***Abstract*— Indoor fish farming quality heavily depends on water quality management. Full-time monitoring can be a way to improve the management system but the conventional manual process cannot ensure efficient monitoring. Human eyes cannot detect all physical and chemical parameters. Internet of Things (IoT) can play a vital role to monitor, manage water quality to flourish the indoor Aquaculture Industry. In this paper, an IoT based model is proposed considering all chemical aspects and a prototype is implemented. A mobile application is also developed for real-time monitoring and controlling all the devices which can stabilize the system if any parameter exceeds the ideal value.**

Keywords*— *Biofloc, Internet of Things, Water Quality Management, Remote Control

I. INTRODUCTION

Now a days Aquaculture Industry increasing rapidly in the world and indoor Fish farm named Biofloc technology (BFT) is becoming popular day by day in fish farming. In Biofloc technology, Aquatic animals are cultivating in a large tank through enhancing water quality. It is considered an efficient system that reused the water. In this system, water is limited in the tank, and fish cultivating for a long time without any change of water. And the key parameters of fish cultivation are quickly changing. Traditionally, water samples are collected and tested, which take time to respond. It is hard to check water quality parameters regularly and changes water according to impurity.

IoT currently plays a significant role in smart fish farming, which helps to observe and to control different parameters remotely. IoT based fish farming is an excellent solution to solve the critical problem. There was a huge Economical difference between smart farming and traditional farming as we found in earlier studies. IoT makes it simple for using different sensors and controlling devices combining with automated communication system.

This paper aims to develop an embedded system, which allows real-time monitoring with a controlling system for the best production of fish in an efficient way. By using cloud based database, data can be monitored in real-time and controlled through a web interface or mobile app anytime and anywhere, which effectively solves the problems of fish culture without the farmer's touch. Without any trouble, this research outcome came successful.

II. EARLIER RESEARCH

Researchers have proposed a system of water quality monitoring and control techniques for aquaculture long time ago but they focus on few kinds of sensors like pH, temperature, water level but water controlling actuator were absent in those ideass. Zougmore et al. [1] designed a system that Low-cost IoT solutions for agricultural fish farmers in Africa with the help of the Internet of Things (IoT), but the limitation is it has no controller that controls water parameters. Encinas et al. [2] proposed a zig-bee based wireless sensor network for aquaculture system that was combined with the temperature sensor, pH sensor, and Dissolved Oxygen sensor but controlling water parameters are not implemented here. The author Raju proposed a system that uses several sensors and data visualize in the web and mobile app but actuators are absent [3]. Dzulqornain et al. [4] developed a monitoring system based on Dissolved oxygen, pH, and Temperature sensor where data visible in smartphone and web application and used aeration pump as an actuator. Based on the Arduino Mega2560 board, Wivity module, DS1302 RTC, LEDs, buzzer, LCD technologies a system was developed that continually determines the ponds water quality and controls water parameters for fish farming [5]. Where the system monitors some variables, which are water temperature, water level, and used only heater as a controlling system. However, they implemented simple analysis instead of considering several important features like pH, TDS, and a simple controlling system for those water parameters. Teja et al. [6] developed a smart monitoring system for pond management, based on ESP 32 DevKit, AWS cloud, and sensor networks for real-time monitoring in a fish pond. This system consists of pH sensor, Ultrasonic sensor, DHT 11 sensor that determines water quality. This system provided sensor monitoring but the limitation of the system is, the actuator control of water parameters is not implemented here.

To maximize productivity, people need to consider the following criteria of water quality and maintain the appropriate standards of these criteria for fish farming. Water temperature is a major element and it has a strong influence on fish farming. Depend on temperature fish larvae can survive. Fish have a low tolerance to sudden temperature changes. The Temperature has other negative consequences as algae, and zooplankton also react to water temperature. It regulates Oxygen level, pH, salinity, and other water parameters which directly and indirectly temperature-dependent. As temperature increases dissolved oxygen decreases and more carbon dioxide is produced in water because hot water has less oxygen in it [7] [8] [9]. For better fish health growth tank water must keep a temperature between 24 °C to 30 °C [9]. Being that in this research we keep the temperature as the driving factor of all processes. However, water temperature not only affects the fish, but also the pH (Potential of Hydrogen) expressing the acidity or alkalinity of a solution that affects the fish. Tank water may be acidic (pH < 7.0), alkaline (pH > 7.0). As pH rates decrease, the ammonia ions (NH_3) chemical reaction to the water to create ammonium ions (NH_4^+) and hydroxyl ions (OH^-), and carbon dioxide (CO_2) [9] [10]. As pH levels increase, they chemically form with water to create poisonous ammonia ions (NH_3) that will infect and destroy fish [11]. For better production efficiency and fish safety at water pH values ranging from 6.8 to 8.5 pH scale. TDS represents the minimum solids in the water that have been dissolved. TDS relies on various parameters including pH, ionic strength, and temperature, and dissolved oxygen concentrations [12]. The TDS is a function of salinity. TDS induces toxicity through a rise in salinity. Increases salinity cause less-tolerant fish species were delayed hatch, as well as long-term effects on growth and development [12]. For good production e and fish safety at the water, the TDS value is set to TDS $\leqslant$ 2500 mg/L [12].

In this paper, the aim is to develop a cost-effective and user friendly remote monitoring and automated controlling system by using IoT technology. Developed controlling system must have a decision making mechanism which can analyze the sensor data. Integration of automatic system will reduce cost and make suitable for fish cultivators for good production and profit.

III. PROPOSED SYSTEM ARCHITECTURE

The proposed model to monitor water parameters and controlling devices is shown in fig. 1. The model can be separated into three blocks in terms of the working principle: Sensing block, Monitoring Block, and Controlling Block.

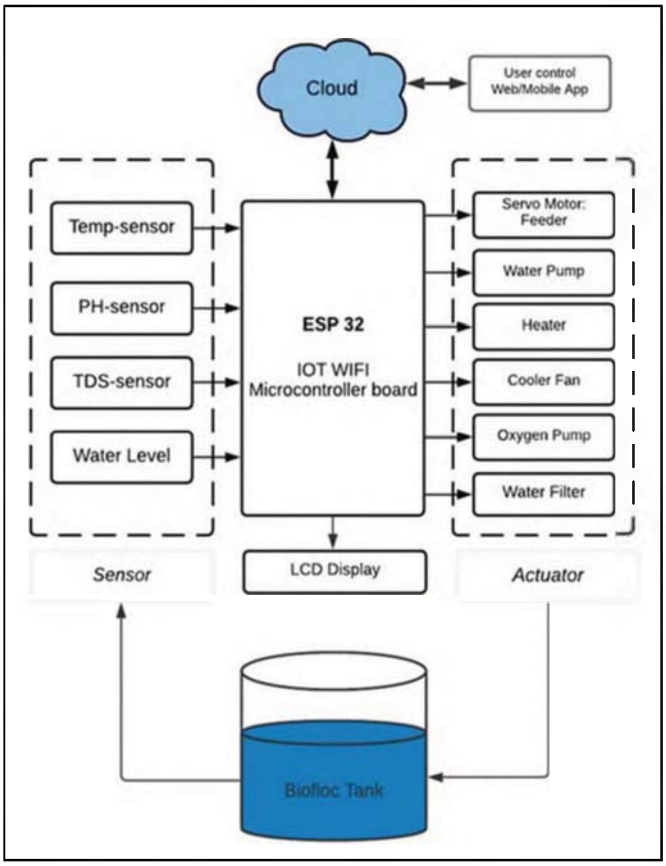

Fig. 1. Proposed System Architecture

Sensing block collect different necessary water parameters such as temperature, pH, TDS, the water level in the tank, and building using sensors. A controlling system is integrated to control water temperature, pH level, automatic fish feeding, and automatic water filling and intelligently water cleaning. Actuators are used here to control water parameters automatically .A mobile application is developed which can easily access to all parameters and real-time data. The sensing block uses a Temperature Sensor, pH Sensor, TDS Sensor, and water level detector. The monitoring block consists of a server, mobile app, LCD monitor in the plant. ESP32 used as a controller board which is a low-powered, low-cost microcontroller (MCU) board, built-in with both Wi-Fi and Bluetooth, and is based on a dual-core processor mechanism [13]. The DS18B20 temperature sensor is chosen in this system to measure the temperature of the water. A pH sensor is used here with a BNC connector to measure pH. TDS sensor for measuring the TDS value of the water, to reflect the cleanliness of the water. A servomotor based Feeder is used to fish feedings to prevent overeating by releasing the right quantity of food, at scheduled times. A heater is used to increasing the temperature of the fish tank. The water pump flows the water from the reserve tank and it automatically 'ON/OFF' according to the level sensor. A filter is used to removing excess food, decaying organic matter, free-floating particulate, dangerous chemicals, and the fish's waste products from the water. Filter is ON after the sensor parameter change from the threshold level. This intelligent framework makes it conceivable to monitoring and remotely control the water condition without any trouble. In an emergency, a warning will be sent to the farmer's mobile app as well as farm automatic controlling system will automatically turn ON the actuators when the levels of the parameters cross the acceptable range and then turn it OFF once levels have returned to a preset acceptable level. For further analysis, information is processed through a cloud server and visualize in a webpage and 'Smart Biofloc' mobile app. That application is also permit controlling actuators manually.

IV. CONTROL SYSTEM METHODOLOGY

Fig. 2 shows the control system methodology behind the proposed model. When the system initializes, it reads the sensor data and directly send it server. Once a system initializes then it must have turned OFF manually. In parallel operation, an LCD that is attached to the indoor system shows the real-time value for the user. Server data can be accessed using a mobile application that is developed in this project. Now a decision-making procedure is introduced which makes the system autonomous. If the temperature is higher than 30°C oxygen pump and Cooling fan ON, else less than 24°C the heater ON. For the pH value higher than 8.5 pH added phosphoric acid that notifies users and oxygen pump ON because higher pH oxygen is low, otherwise pH value lower than 6.8 pH display shows that added Baking soda and water filter ON. If the TDS level crosses 2500 mg/L the water filter ON, to clean water. The Biofloc tank is full of water if the water level $\geqslant$ 100%, the water pump automatically OFF, otherwise if the water level lower than 80% the water pump automatically turns ON. All actuator statuses go to the cloud that the user can keep monitoring which actuator is ON or OFF the current status. The acquired data and status of the actuators all were shown in the LCD, Android app, and Web application.

V. SYSTEM PROTOTYPE & ITS GRAPHICAL INTERFACE

This section shows the graphical user interface of the developed prototype. The application is divided into few subsections like Real-Time Monitoring Data, Weekly Data, Daily Data, Control System, and a path to the app where data monitor and control possible. The data can be monitored from the android mobile application as well as a web application. It can be controlled though both platform.

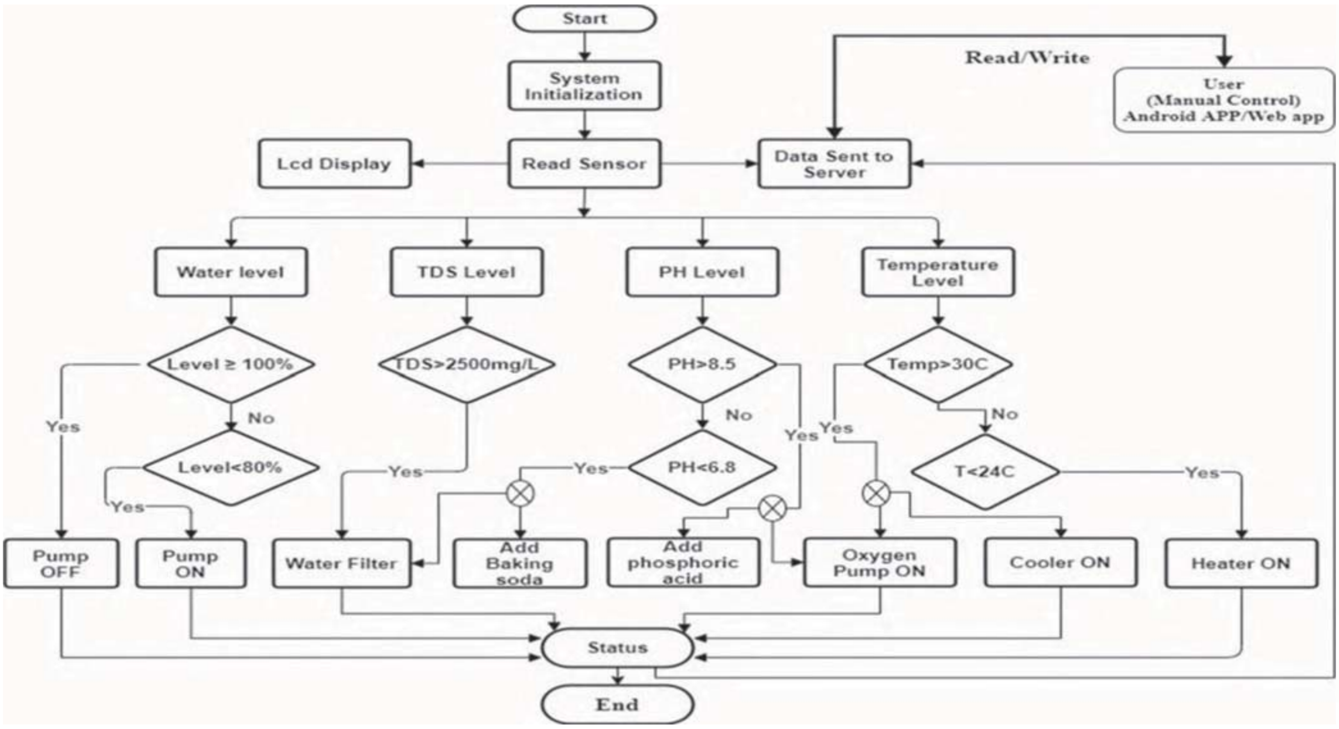

Fig. 2. Biofloc Control System Flowchart

Fig 3 shows the prototype of the system. Here bulb was used as the water heater. According to the logic of the system, the bulb glows when the heater will start. When system needs to increase the water temperature the heater switch turn ON automatically.

Fig. 3. Top view of the prototype

Fig 4 shows the real-time data which is monitored by the system. Here, Temperature is showed by Temp, pH values by pH, TDS means the water Total Dissolved Solids value and the water level detects the level in percentage. These values are changing in real-time and updated regularly as the sensor value is also changing. An alarm and message section is added because if any sensing parameter crosses the threshold level this app section will notify the user that the user can understand the Biofloc tank current problem. After control all water parameters the message is automatically removed.

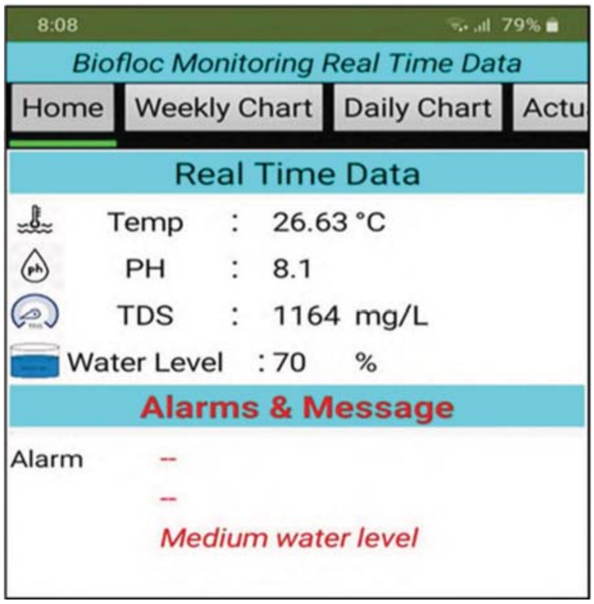

Fig. 4. GUI of Real Time Data

Fig 5 shows that, controlling the system where a user can monitor and control which actuator is ON or OFF. When the actuator switch is the red color that is the actuator's current status. That means the red block situation actuator present state. If the red color indicates the OFF button that means the actuators are OFF now, else the red color indicates the ON button, which means the actuators are ON now. Users can easily and remotely turn 'ON/OFF' any actuator by using the app. From Figure 5, observed that the inlet water pump switch is in ON state and other switches are now in OFF state.

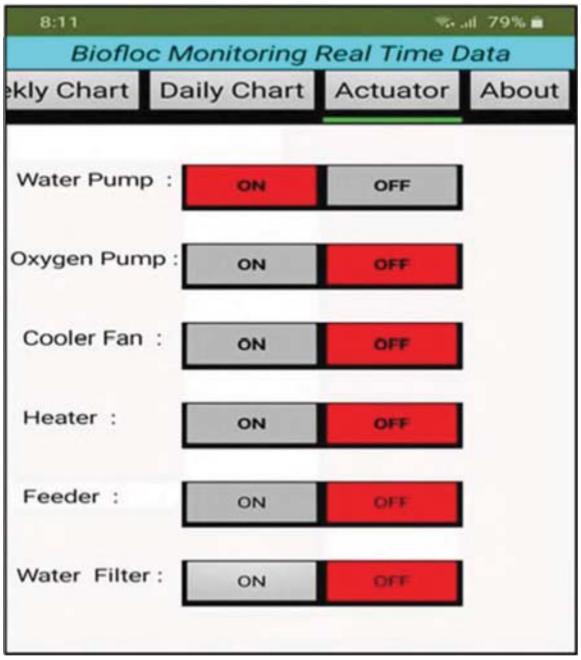

Fig. 5. Biofloc App Actuators GUI Live Status

Data collected here to check the stability of the system and to study the comparison to the traditional Biofloc system to cultivate fish. Smart Biofloc system monitor all data to keep good water health and produce more products that a farmer expect from fish farming.

VI. RESULT ANALYSIS

In this paper, the proposed architecture is implemented successfully using the presented hardware, architecture, and software.

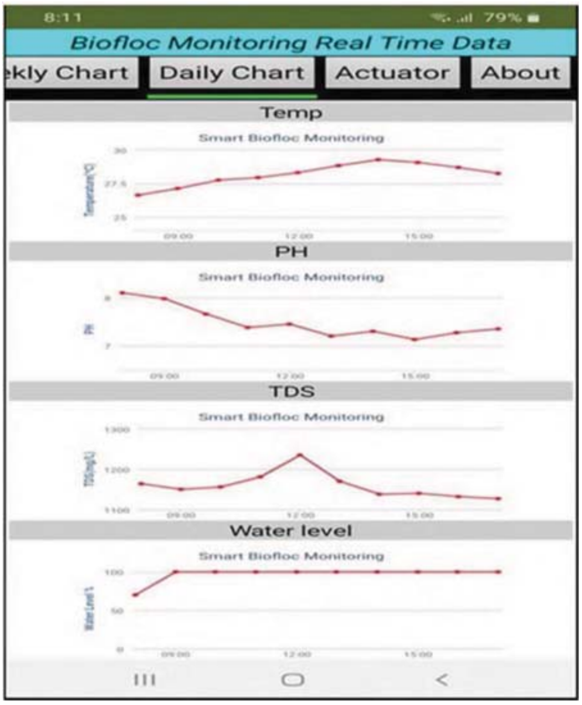

Fig. 6. Biofloc App GUI of Daily Data

Data read from the sensors are presented in Fig 6 and Table 1, and full system status shown in Fig 4, for transmission without any high level of errors. For good production in the fish farm as well as keeping fish health, actual sensing results are required. Fig. 7 shows few samples of data taken from LCD display during experiment.

Fig. 7. Biofloc LCD Display

From Table I, The variation of different parameters can be noticed as the time goes by. Temperature increases during midday but it does not cross the threshold temperature. So the Oxygen pump is not open. Due to change in temperature, the pH also varying. Underwater photosynthesis usually exceeds respiration during daylight as plants resume photosynthesis and remove carbon dioxide from water so that pH increases as the water extracts Carbon dioxide [10]. As we know the conductivity increases with increasing temperature. Conductivity is often correlated with the concentration of salinity and TDS. Higher conductance causes higher TDS [14]. So Temperature changes cause a change in TDS as observed in Table 1. From Figure 6 above, the water level is at 70 % at the initial stage, which is low than the threshold value so that its inlet water pump ON that shown in Figure 5 and it began to increase the water level. This is because the system has found that the water level is lower than the 80 % desired water level, so the water pump begins to fill some water in the Biofloc tank to match the desired measurement, after some time the desired water level is reached.

TABLE I. VALUES OBSERVED FROM BIOFLOC TANK

Time	**Water Quality Parameters**			
	Temperature (°C)	**pH**	**TDS (mg/L)**	**Water level (%)**
8:00 am	26.63	8.1	1164	70
9:00 am	27.13	7.98	1150	100
10:00 am	27.75	7.66	1156	100
11:00 am	27.94	7.38	1181	100
12:00 pm	28.31	7.45	1235	100
1:00 pm	28.83	7.2	1170	100
2:00 pm	29.27	7.3	1138	100
3:00 pm	29.06	7.13	1140	100
4:00 pm	28.69	7.27	1132	100
5:00 pm	28.25	7.35	1127	100

In the Smart-Biofloc system, sensors measure the tank environment and the controller board decides on how and when to maintain the tank using actuators. It's very hard to monitor everything going on inside Biofloc around the clock with regular maintenance. Manually if it fail to maintain the Biofloc tank in proper time, the fish will be stressed by poor water conditions will cause production loss as well as economic loss. In Smart-Biofloc system can remind the fish owner what to do in water variation out of threshold value through an alert mechanism. Thus it will ensure the safety of the tank and also a quick recovery if any parameters show abnormal value. People can reduce financial loss during farming and take better observations in the future. The total cost of the system 4500 BDT which is affordable for fish farmers and very low compared to the profit increment by using the device.

VII. CONCLUSION

The proposed model can be used for monitoring water temperature, water level, pH, and TDS and controlling different pumps and motors automatically.Farmers can easily monitor, evaluate, and manage their farms through online by using the mobile application from their home. The developed system is closed-loop so automated decisions will be made by the control system during monitoring. The farmer might also, override and manage things manually. The combination of sensors, cloud system, mobile app, and controlling devices make the fish farming system strong, efficient, and more productive. This system not only lessens employment costs but also increases the economic growth of fish farmers.

In the future, system performance can be improved by monitoring Dissolved oxygen (DO), Electrical conductivity (EC), Ammonia parameter, and developing self-sustaining renewable energy power system.

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