Smart Aero-Spider: An adaptive and selective smart switching aerator system

Shubham Yadav¹, Yashas Bharadwaj², Arjun Hariharan³, Amit Choraria⁴, Atharv Tendolkar⁵and Dr. Manohara Pai M M⁶
¹,²,⁴,⁵Department of Electronics and Communication Engineering
³Department of Electronics and Instrumentation
⁶Department of Information and Communication Technology
¹shubham6yadav@gmail.com, ²yashasbharadwaj58@gmail.com,
³arjunhariharan20@gmail.com, ⁴jainamit130@gmail.com, ⁵atharvten@gmail.com,
⁶mman.pai@manipal.edu.

Abstract. The recovery from the COVID-19 pandemic hit shows the emergence of increase in quality of life across various parts of the world. With this lifestyle change, people are looking towards high quality food. Fish being a major source of protein, the industry producing fish from aquaculture is booming. The proposed smart aerator system provides an integrated array of underwater systems for selective aeration of the water body. The smart system ensures targeted aeration to guarantee optimal levels of dissolved oxygen at all times. This is beneficial for perfect survival, growth, and reproduction of fishes. The strategically placed spider aerators are turned on when readings from the dissolved oxygen level at the location is below the optimum range of values. The air blower system consists of an intelligent switching system to activate the right aerator based on the requirement. The sensor data is relayed to the cloud with a wireless communication module. This data can be used for useful insights and all-round monitoring of the water body. The respective aerators have IR sensor to detect movement alongside on-board LEDs to indicate functioning status. Overall, this ensures maximum accelerated growth of healthy fishes. Thus, the solution aims at efficiently boosting the ability of the aquaculture industry to meet the ever-growing demand of consumers.

Keywords: IoT, Edge Computing, Arduino, Thingspeak Cloud, Sensorics, Optimization, Sustainable

1. Introduction

With the world’s per capita of fish consumption rising exponentially due to the increasing population in third world countries, it is apparent that we need to increase the fish production and culture to meet the rising demands of people [1]. The inspiration for the same was drawn after talking to various fish farmers and the hardships faced by them during monsoon season when it is advised against going to the sea because of cyclonic winds. As a consequence of this, the farmers hardly earn any money and resort to other low wage jobs. Apart from this the farmers also mentioned that the number of fishes has declined drastically over the years and had to look for other alternatives. Reasons such as global warming and overfishing are two major reasons which hampers aquatic life. The smart aerator is one of the several modules in the customised aquaculture tank. Since the growing of fishes in an enclosed tank with little or no connections to the natural world, the environmental factors such as temperature, DO, TDS etc tend
to differ drastically, thus shortage of dissolved (DO) oxygen to breathe is one of the many fundamental issues faced during the development [2]. High levels of dissolved oxygen in water causes gas bubble disease which can ultimately kill the fish and on the other hand low levels of oxygen can invite bacterial infections as well as cause fatigue. The ideal range of dissolved oxygen is from 7mg/l to 9mg/l. Most of the fish species cannot survive below the level of 3mg/l. The temperature in the tank also affects the daily fluctuations of DO in the tank [4, 5]. Thus, a smart aerator system that works real time to keep the dissolved oxygen at an optimum level is crucial for rearing healthy fish. The smart aerator module encompasses a computing module based central processing hub, multiple sensors mounted on the spider aerator and a splitter for controlling multiple aerators individually with a pump. There exists a temperature sensor stuck to the body of the pump which measures the pump’s temperature and if it crosses beyond a particular temperature set point, it automatically triggers the computing module to turn off the pump. The module is able to analyse the DO sensor data and when the DO level in the water reduces below the optimum value, the pump gets triggered through a relay and through the wireless communication module, the data is sent to the Thingspeak cloud real time. The parameters that are monitored through DO sensor, IR sensors in multiple aerators, LEDs to indicate the operation, temperature sensor on the pump is processed at the core of the aerator module using a computing module, along with a wireless communication enabled computing module which helps in relaying the sensor data to the aquaculture central server. The data sent to Thingspeak cloud helps the user to be up to date with the tank condition along with real time monitoring capabilities. The individual aerators can be controlled manually through the Blynk application via phone for more physical control over the DO levels in the tank. What sets the Smart Aerator apart is its ability to maintain optimum oxygen levels in all conditions and thereby empower the fishermen to have a healthy throughput across all the seasons. The splitter mechanism is controlled autonomously by analysing the amount of oxygen present in water and turning ON the required number of aerators in the water body. It has intelligence of its own, powered by on-device computing. This enables it to take decisions on-site instead of consulting the cloud for processing and actuations. Hence, the smart aerator module redefines aquaculture in the 21st century by mitigating the hardships caused due to undulating climate factors.

2. Literature Review

Integration of various parameters on a module is of paramount importance which requires intelligence at every node of the system along with that at the central server. Extensive research and development are going on in building autonomous robots and self-driving cars lately. But despite extensive research done in the aquaculture sector to reduce the dependence on the natural resources for growing fishes, an integrated smart module has not been designed such that it is both affordable and economic at the same time and can be used by industrialists and fishermen in India alike. Data analytics which include collection and processing of data is very crucial in the development of this technology. Such a technology can alert the user after the data processing and also provides remote accessibility. Here ZigBee wireless protocol has been used to communicate between the devices and the network [5, 6]. Designing the right IoT framework must be given importance since it provides good user experience along with reliability and security of the infrastructure [7, 8]. Users can now interact better with the onboard sensors with the touch of a finger, and upon that the framework follows a specific data-flow modelling. Users can now access critical information through two step verification and through secure communication protocols (MQTT – MQ telemetry transport) validated with system APIs [5]. Adding to all these ideas, the modern solutions need optimised and creative data points to work on along with parameter triggers and stream flows [8]. But what sets this new solution apart is its seamless user experience and completely automated module from switching off the pump to theft alert system and aerator trigger mechanism all done without any human interaction. Above all it comes with an economical and sustainable module which can be used by even a layman who is new to the IoT or cloud
technology. A coherent User manual is accompanied with the offering of the Smart Aerator module which will enable all type of users to make use of the smart aerator effectively.

3. Proposed methodology

3.1. System Architecture
The architecture of the Smart Aerator system can be divided into 4 tiers. Figure 1 by the author shows the process flow for the 4 layered architecture.

1. Intelligence: Physical parameters like dissolved oxygen level is compared to a set point and further decision for actuation is taken.
2. Actuation: Helps in enabling aeration for a specific sector of the water body with the help of motors and splitters and an array of multiple aerators.
3. Feedback: The physical parameters data is fed back to the intelligence unit for analysis and on the cloud platform for the users' needs.

![Figure 1. System Architecture.](image1)

3.2. Structure and Schematic
The smart module system has a structural framework with multiple components at the ground level as well as underwater in the water body. Figure 2 by the author shows the overall schematic of the setup.

![Figure 2. Structure and Schematic.](image2)
• The structure consists of multiple spider aerators placed strategically which help in uniform aeration of the water body based on requirement. The triggering of the right aerator is achieved with the help of real time readings from the dissolved oxygen sensor.
• Implementing targeted actuation involves a splitting mechanism which consists of an air splitter with servo motors attached to it for controlling the knobs.
• Air pump with proper flow rate required for the specific application is chosen based on the number of aerators and area of water body to the aerated.
• The pump as well as the splitting mechanism is controlled by the main computing module which is the core of intelligence of the structure. The physical parameters such as Dissolved oxygen levels are further uploaded to the global platform Thingspeak via wireless communication modules and routers [10]. The data uploaded can be used for real time analytics as well as for visual feedback of the status of the water quality.

3.3. Practical Development

![Block Diagram](image)

**Figure 3.** Block diagram representation of circuit.

• Figure 3 by the author shows the block diagram of the experimental circuit with a dissolved oxygen sensor connected to the Arduino.
• Relay for controlling the pump, servo motors for switching mechanisms are connected to the Arduino and subsequently data for the status of these components is uploaded to the Thingspeak cloud.
• The actuation of these components is based upon the level of dissolved oxygen in water which is compared to a predetermined set point stored in the system, these components can also be controlled via the Blynk application [11] which is connected to NodeMCU via wireless communication.
• The connection between cloud and Arduino is facilitated by ESP8266 NodeMCU which is constantly communicating with the Arduino and uploading data via the wireless communication network.
• Read and Write API keys are used for communicating with the cloud which ensures safe and secure connection.
• The circuit can be actuated by the user through Blynk application or manually with the push button provided on the blower system or automatically based on the data from the dissolved oxygen sensor.

3.4. Circuit Development
The circuit for smart aerator can be divided into 3 major segments namely the air blower system, splitting mechanism and the water system as shown in Figure 4 by the author.

3.4.1. Air Blower System:
• The most important component of the air blower system is the computing module which is the intelligence stage of the system.
• Arduino Uno is the computing module in this system which takes care of all the analog data from various sensors which are connected to its analog pins.
• The Arduino also relays this data to the wireless communication module for uploading it to the cloud.
• The communication module and Arduino communicate via UART communication protocol [9] that is through the Transmission and reception pins present.
• The air blower system also includes a relay switch which is an electronically actuated switch for turning the ON the pump. It is controlled by the onboard computing module.
• Push button for turning ON the whole system, temperature sensor for keeping the temperature of the air pump in check and switching OFF the circuit once it crosses a threshold temperature, and LED strips for indicating the mode of operation of each aerator is also connected and controlled by the computing module.
3.4.2. Splitting mechanism:

- The splitting mechanism consists of an air splitter with 1 inlet port connected to the pump and the number of outlet ports is equal to the number of aerators used.
- Each outlet port has its individual knob which has a high torque, metal geared servo mounted on top for turning it to open and close the port.
- Multiple outlet ports can be opened at the same time based on requirements and each can be controlled individually from the computing module.
- This actuation can also be done by the Blynk application through wireless communication module.
3.4.3. Actuation System:

- It consists of an array of spider aerators; the total number of aerators depends upon the volume of water to be aerated. Each spider aerator has an aeration rate of 30 liters per minute.
- Dissolved oxygen sensor is placed to give the dissolved oxygen level in the particular area of the water body directly to the main computing module.
- Each aerator has an LED strip stuck to its body for representing the mode of operation similar to that present on the air blower system and an IR sensor for detecting lift up and warning the user about it.

![Actuation System Circuit](image-url)

**Figure 7.** Actuation System Circuit.

4. Results and Discussion

4.1. Circuit Realization

![Overall circuit diagram](image-url)

**Figure 8.** Overall circuit diagram.
The circuit diagram in figure 8 gives the general overview of the entire circuit of Smart Aerator which includes all the components from the three parts. Figure 9 shows the implementation by the author of the various modules included in the blower system like the main computing module Arduino Uno, and Wi-Fi module for wireless connectivity, communicating via UART protocol with Uno, LM35 Temperature sensor for keeping the temperature of the pump in check, Relay module for switching the power supply to the pump, push button for manual control of the whole circuit, RGB LED for indicating the mode of operation with different color combinations.

![Circuit development for blower system](image)

**Figure 9.** Circuit development for blower system

4.2. **BLYNK Application**

BLYNK App enables us to communicate with the wireless communication module which is used for giving user the control of the entire circuit like turning the main pump ON and OFF and selecting a particular spider aerator to perform aeration which turns that servo by 90 degrees. Figure 10 shows how the user interface looks like with buttons for each aerator and main pump.

![BLYNK App interface](image)

**Figure 10.** BLYNK App interface.
4.3. Spider Aerator
The output of the splitter is connected to the respective spider aerator which is capable of producing microbubbles [12] which help in uniform aeration and does not interfere with the aquatic life. Figure 11 demonstrates how a spider aerator works by the author.

![Spider aerator and successful aeration.](image)

**Figure 11.** Spider aerator and successful aeration.

4.4. Anti-Theft system
An IR sensor is attached to the body of the spider aerator as shown in Figure 12 by the author. Along with the RGB LED to detect if an intruder tries to lift the aerator and warn the user. The color of the RGB LED also changes accordingly.

![IR sensor detecting lift and correspondingly changing the color of RGB LED.](image)

**Figure 12.** IR sensor detecting lift and correspondingly changing the color of RGB LED.
5. Conclusion
The proposed idea of smart aerator can control the dissolved oxygen level autonomously without any human interaction as such. Apart from the control system it has to offer, it also has an in-built theft alarm through which the user gets alerted when the aerators are lifted. When the pump crosses a particular set point temperature, it turns OFF automatically. Above all this, the user has the control over all the splitters operated through the BLYNK application to provide the liberty to control the DO level manually. This idea will enable the farmers to rear fishes during trying times with least efforts and due to its sustainable and economic approach, it can have a bright future ahead. Moreover, the farmers can safely and securely evaluate their fish tank from any part of the world and get maximum yield out of it.

6. Future work
The smart aerator is coming to its final stages of completion and is being tested under various environmental conditions also called as beta testing to calibrate the sensors well and making it adaptive through sensor fusion and former data values. Smart Aerator has many more features than what meets the eye. It can be scaled to multiple platforms and can be similarly used for other environmental factors like temperature, pH, TDS etc. The whole tank can be controlled remotely from anywhere in the world more efficiently and precisely. This module can be used as a central hub for all farm services and can be used to maintain the temperature, TDS and pH which are very crucial for rearing of fishes. Automation tasks can be now integrated with the smart aerator module with ease through IoT network lattice and the intelligence at every node can be further enhanced by processing the data via local edge computing cloud infrastructure hence making it a multi-functional module. Upon all this it uses sustainable technology and further solar panels can be used to power the whole circuit and the pump without usage of batteries which adds reliability and performs tasks diligently. The circuit diagram, yet fundamental, performs very efficiently. User centricity, sustainability in farming and power efficiency is what sets this device apart. The smart aerator will provide the right data to the user so that the farmer is assured of safe and quality fishes ready to be sold to the public. In the future, the read API key taken from the Thingspeak channel can be used to obtain the data analytics for the whole tank which includes the Temperature, pH, and TDS sensor data and this can be used in writing a python or a MATLAB script to obtain the same. This will further enhance the fish growth by suggesting steps to ameliorate the overall farming experience. Hence Smart Aerator provides a sustainable, ergonomic, and efficient solution to all the problems that the farmers face during these trying times with its multi domain applications, massive scalability and most importantly simple but efficient circuitry serves as a perfect companion for the modern age IoT farmer.

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