Research and Postgraduate Studies (RPGS) Unit

Thesis title: AUTOMATED FISH EGGS INCUBATOR WITH SMART CYLINDER

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COLLEGE OF SCIENCE AND TECHNOLOGY

MASTER OF SCIENCE DEGREE IN INTERNET OF THINGS-EMBEDDED COMPUTING SYSTEMS

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Thesis Title: AUTOMATED FISH EGGS INCUBATOR WITH SMART CYLINDER

By

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A dissertation submitted in partial fulfilment of the requirements for the degree of

IN THE COLLEGE OF SCIENCE AND TECHNOLOGY

Supervisor: Dr. Alexander NGENZI

Co-Supervisor: Dr. Alfred UWITONZE

Month and Year of submission: May 2021

DECLARATION

I, Mr. NGABOYERA Eric, declare that this thesis is my original work and has not been submitted before for any academic award either in this or other institutions of higher learning for academic publication or any other purpose. The references used here from other journals or materials are indicated in the references section.

NGABOYERA Eric

213001416

Signature: ………………………….

Date: ……/……/……

BONIFIDE CERTIFICATE

This is to certify that the project entitled" AUTOMATED FISH EGGS INCUBATOR WITH SMART CYLINDER" Is a record of original work done by NGABOYERA Eric with reg number 213001416 in partial fulfilment of the requirement for the award of masters of sciences in Internet of Things in College of Science and Technology, University of Rwanda, Academic year 2020

This work has been submitted under the guidance of Dr. Alexander NGENZI and Dr. Alfred UWITONZE

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ABSTRACT

Aquaculture is becoming an attractive field of farming as a profession in Africa which acquires a huge number of young fish productions. Therefore, aquatic life is naturally a hazardous environment for egg to fry development, which brings a big difference between rate of eggs production and release of fries. The incubation of fish eggs is necessary to monitor environmental changes against eggs. The way this technique is applied, is manual and it causes mortalities of several fish eggs. Even though system automation is a good solution for this problem by maintaining some critical parameters such as temperature at ease for eggs to survive, the problem of slow response time still persist since fish breeders requires them to work closer with the system to see what's going on.

This research focuses on "**automated fish eggs incubator with smart cylinder"** by monitoring different environmental changes such as; oxygen level, mechanical damage, water temperature, and flow rate and water quality. These parameters are respectively controlled by a network of sensors such as; water flow sensors, temperature sensors, and PH sensors. The data corresponding to these parameters are stored on the cloud for further research and analysis and remotely monitored by the person involved. This system is affordable due to its low power consumption, easy portability where can be taken by breeders during fry release.

Key words—Internet of Things, IoT, Fry release, Fish eggs, Sensors, NodeMCU, Node-RED, Cloud, Fish Kills, SMART, and Automation.

List of Acronyms

ACEIoT: African Center of Excellence in Internet of Things

DMRS: Domestic Market Recapturing Strategy

Dr: Doctor

ESP: Espressif

GPIO: General Purpose Input/Output

GSM: Global System for Mobile

IBM: International Business Machines

ICT: Information Communication and Technology

IDE: Integrated Development Environment

IoT: Internet of Things

LCD: Liquid-Cristal Display

LED: Light Emitting Diode

MCU: Microcontroller Unit

MQTT: Message Queuing Telemetry Protocol

pH: Potential Hydrogen

SOC: System On Chip

TCP/IP: Transmission Control Protocol

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CHAPTER 1 GENERAL INTRODUCTION

1.1 Introduction

Around the world, aquaculture has started artificial fish eggs incubation as a new practice to increase the economic efficiency of a commercial fish culture operation. Generally, Incubator is a place wherein fish eggs are kept under conditions favorable to normal development to ensure their proper development and better survival where it can provide a constant flow of water for preventing any accumulation of waste products and allowing gas exchange between the egg and the surrounding water.[1]

By evaluating the comparison between natural incubation and artificial incubation in terms of production, quality, and survival of eggs, subsequent growth and survival of fry, it has been found that survival during artificial incubation 85% is greater than in natural incubation [2].
A man-made incubator has ability to simulate natural processes of hatching eggs, where it can prevent eggs from damage, in addition, it controls and manipulate environment against predators which is mostly present during natural incubation.

A wide variety of devices are used for incubating fish eggs. For practical purposes, we have classified fish egg incubators into three major types: egg mats which are used primarily for adhesive eggs, trays which are ideal for fish eggs that can be injured by movement during incubation, and fish eggs that are non-adhesive and require constant movement are commonly incubated in conical shaped tanks or jars where water flows into the bottom or top of the container. My focus in this research is conical shaped tanks or jars incubators which will better be put indoor located nearby the pond, noting that any outside environmental stress will negatively impact on the fish egg growth to fries.[1]

As the time taken by the eggs to develop generally varies in different fishes, it can also vary with the temperature during incubation.[3] Therefore, temperature is one of the many key parameters that is needed to be monitored, combined with other important factors like light intensity, mechanical shaking, water flow rate, oxygen level, etc. The above-stated parameters hold an interdependency among themselves which brings to the human mind a very complicated series of events in the fish egg development process.[4] [5] Researchers have illustrated the simple different ways of making an incubator depending on one's need which will save water, space, and money.[4]

They have been doing researches on the automated system which can control many of environmental parameters such as temperature and the system which can remove dead eggs automatically for constantly purified water.[6] This advancement in fish eggs incubation shows a great honor to researchers, especially in the aquaculture field. Remember that fishes are more sensitive to environmental conditions so as it is difficult to raise them in an artificial environment, consequently fish farmers are still struggling with deception from several eggs or fries die instantly due to environmental change without awareness and response of the farmer.[7] In Rwanda, some have started their incubators, but it often requires staff to make always sure there is no problem with eggs. Some of the problems they often face as an example are temperature rise which may not be known in time. I am focusing on this awareness of environmental changes through an automated fish egg incubator with a smart cylinder which will allow the farmer to receive the updates about what's going on inside the incubator for a remotely monitor some of the parameters when an emergency is required. This system will be portable, low cost and allows sharing information the farmers through the cloud to be used for further researches and aquaculture activities.

1.2 Background

Fish accounts for 17 percent of the world's animal protein intake and 6.7 of all protein consumed. Fish farming has played an important role in providing more fish and helping to keep fish prices low. This situation has increased the number of actors involved in food security not only to farmers and agricultural specialists, but also to researchers who strive to develop new techniques that will increase food production with an effective return on investment methodology.[8]

Rwanda's fish production has grown steadily in recent years; it is still weak and cannot meet domestic demand, which should continue to grow in the years to come. The country is still a net importer of Nile tilapia, which accounts for over 90% of consumption in the domestic market. However, the growth potential of aquaculture is considerable.

In the light of this situation and in line with the GoR's proposed domestic market recapturing strategy (DMRS), this business case proposes investment in:

1) Commercial production of fishmeal made from locally available small-sized fish species (haplochromines), for both human consumption and animal feed manufacture (as ingredient for the production of feeds for poultry, pigs and farmed fish);

2) Aquaculture of Nile tilapia and catfish. Two options are considered: (i) cage fish farmingand (ii) tank-based aquaculture.[9]

The quality of the water in fish ponds is a major success factor in pond aquaculture. The welfare of fish is highly dependent on the quality of the water in which they are raised (Towers, 2015). Different fish spices require varying ranges of various water parameters in order for them to thrive. Variations in aspects of water quality can adversely affect fish and, in many cases, result in fish death. The quality of the pond water can change rapidly, hence the need for constant monitoring and emergency response to changes.[8]

It is almost impossible for the traditional hatcheries to produce and supply a large quantity of fry using traditional methods. Artificial incubation of eggs will increase the fry production and economic efficiency of a commercial hatchery operation [5]. Moreover, fry produced from artificial incubation system are of known age and therefore suitable for application of hormone treatment for the production of mono sex male fingerlings.[3]

1.3 Problem Statement

Growing fish eggs has to be in a way that they are totally isolated from environmental changes where egg's life is effectively communicated with breeder within a very short time. Breeding of animals requires staying nearby to them though; water life seems to be isolated from our own.

It makes one unable to get in touch with the fish because they live in the water however, even small changes in the water make a big impact on the health of the fish. We raised fish in the ponds to get closer to it but otherwise, it is not what prevents it from being in the water which makes it difficult for us to know its immediate life.

Using technology to detect instantaneous changes in water such as temperature, etc. though, it is still difficult for us because the health of the fish and the life of the eggs are very different in terms of resistance from changes of water parameters and self-protection against predators.

An incubator was a good way to separate fish eggs from a lot of chaos but there is still a great obstacle because it still requires a person to come and check that there is no problem and when an emergency issue arises and one is far away, there is no other way to fix the problem. Due to the above problems following in disregard or delay in rescuing the egg life due to unexpected environmental changes resulting in the death of a large number of eggs

To grow a large number of eggs the IoT system must be used to connect the incubator and the cloud system where any authorized user can access the information and can remotely control the system when needed.

1.4 Study Objectives

1.4.1 General Objective

The general objective of this study is to make an automated fish eggs incubator which can communicate the information to the breeder and let him control some of the parameters remotely whenever it is required. This will be a system made up of IoT devices such as sensors, microcontrollers, and network devices to help interaction between the environmental conditions and the breeder.

However some of those parameters will not require to be remotely regulated like bouncing, I expect to control at least some of these parameters which are temperature, oxygen level, and water flow rate such that a farmer will be notified and whenever some parameters go beyond threshold he or she may regulate to the desired value.

1.4.2 Specific Objectives

In practice this study has the following sub-objectives:

- Develop a system that supports incubation of eggs to lessen the number of premature dead eggs, due to environmental changes, while increasing the number of baby fishes on the market.

- Develop a portable system by fixing all the components in a single kit
- Develop a system which saves power by using low-power devices
- Support in analysis and other investigations on aquatic life by using data stored on cloud

1.5 Hypotheses

This project will provide data through the internet on water parameters inside the incubator such as heat, pH, oxygen, and water pressure in the incubator

1.6 Study Scope

The research focused on developing an IoT based incubator which will take the fertilized fish eggs and they come out on fry stage when it can be fed. The eggs come in water with a monitored temperature, pH, flow rate, and oxygen level and the monitoring of this system will be done through internet. The hardware platform used incorporate more sensors as single portable device.

1.7 Significance of the Study

In this research, water pH, oxygen, temperature and flow rate will be measured by using sensors and sent to microcontroller for analysis then to cloud. Farmers and experts in fish farming will access the data through internet. The system will allow the user to view data on dashboard using NODERED and can also analyse data using GRAPHANA. Fish breeders will benefit from the reduced number of premature death of fish eggs and the ease of getting a sufficient number of small fishes near their ponds. The ministry of agriculture during research will also find data so easily because it will be available on time and updated as well. These impacts may be measured by comparing both the existing and proposed system.

1.8 Research motivation

The motivation to carry out this research was taken from the rate of consumption of fishes in Rwanda as published by Rwanda Agriculture and animal production board that the availability of good quality seed is a key to the development of aquaculture industry. By considering the high demand for seed with the fast upcoming cage culture investments, fish farming in Rwanda is constrained by lack of reliable sources of quality seed. And 5 million fingerings produced by Kigembe National aquaculture station every year will not be enough and more seed production sites need to be established. [10]

1.9 Organization of the Study

This work is organized into six chapters:

Chapter 1: General Introduction, this chapter focuses on Objectives of the project, Problem statement, project Scope, Hypothesis and Methodology of the project.

Chapter 2: Literature review, this offers theoretical concepts regarding the related work done by the other researchers.

Chapter 3: Research Methodology; this focuses on application development methodology that can be used on the project and the data gathering techniques.

Chapter 4: Analysis and Design; this chapter focuses on the analysis and the design of the project.

Chapter 5 focuses on the results of the projects and discussions

Chapter 6: The last chapter is made up of the conclusion and recommendation for further improvements in the project.

1.10 Conclusion

The brief description of this project stated in this chapter includes objectives, problem statement, and the methodologies that will be used to prepare the prototype for the solution.

It also sets out the main assumptions that the project intends to achieve at the end of Chapter 4; design and implementation. Related work and Literature review are well detailed in the following chapter.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter presents a discussion of the difficulties farmers face in monitoring water quality, key parameters used in aquaculture water monitoring, and the impact of those water parameters in the development of fish eggs. The different application architectures used for monitoring water quality inside the incubator were reviewed and used as a basis to develop the model which was an improvement of already existing models.

2.2 Automate fish eggs incubator and water quality monitoring

2.2.1 Related work

Raspberry Pi has been used to monitors aquaculture where quality of water is monitored continuously with the help of sensors that are mounted to sense the data and transfer them through IoT to the aqua farmer mobile to ensure growth and survival of aquatic life. They used an integrated on-chip computer Raspberry Pi which has an inbuilt Wi-Fi module which makes it unique on the IoT platform. After this, the collected data can be analysed using big data analytics preventive measures that can be taken before the water quality parameter crosses the threshold range. Since the system is automated using IoT it reduces the energy consumption and labour cost. [8] This research has not focused on fish egg however; its health should be taken into account in particular by preventing its contact with other fishes using incubator and monitor the flow rate inside the incubator.

The fishery management was proposed by using these sensors (temperature sensor, water level sensor, and PH sensor) all the work is automated and it also is easy to monitor fish farming remotely from other locations. Also other hardware modules added to allow the end-user to monitor and control vital parameters in the most remotely fish pond locations whereby end-user requests, in this system ARDUINO platform can be remotely configured as a remote server or client with ease as well as other hardware settings. This research has not focused on fish egg however; its health should be taken into account in particular by preventing its contact with other fishes using incubator. [5]

Design of the framework for aquaculture was also implemented with a real-time monitoring solution for measuring the physicochemical parameters of water and a decision support system for data storage, monitoring, analysing and sending the right information to the right persons involved at the right time. Water temperature, dissolved oxygen, water pH, and water turbidity were also measured and their readings were displayed on the LCD screen. The sensor node from this system sends the data to the nearby base station, and then from the base station to the central monitoring station located at the main department. The monitoring process of the proposed system was done by analyzing those data with logic to check whether the threshold level is violated or not according to the readings and decides to send a control command to base station and from base station to actuators to balance physio-chemical parameters of water to its proper level. Solar-powered with chargeable battery also was deployed in this system for energy-efficient. [9]

An exploration and comparison also was done between two incubation systems; Atkin and aquarium with jar incubation system in terms of water use, hatching rate, and subsequent survival of larvae. The system illustrated hatching rates obtained as a function of the different systems of egg incubation tested were presented respectively in jar incubation, Atkin incubation, and Aquarium incubation systems as 95.5±0.6, 57.8±2.2, and 65.2±7.7%. As presented by the test above, they found that hatching percentage was significantly higher in the jar incubation system compared to Atkin and aquarium incubation and be used as an alternative of jar incubation system especially where water is scarce like Nile tilapia eggs. This study was conducted as general guideline in the design of fish eggs incubator where you can choose any type of incubator according to water use and hatching rate. [3]

An automated incubator for Pelagic Fish Eggs is already in place also which has the purpose of constructing an egg incubator with automatic removal of dead and strongly infected eggs, with reduced water demand and with individual temperature and salinity control. A better water circulation and more effective water exchange were achieved due to this system. The system uses water temperature to control the rate and predict the day of hatching. To trap dead and infected eggs, the system produces a downward water current along the walls of the funnel preventing dead eggs settling in order to trap dead and infected eggs in a small chamber where the exchange of water between that chamber and the incubator itself is very slow and finally dead and infected eggs are removed by applying pulsed water through their chamber. This system solved a major problem by removing dead eggs from the incubator even though it did not include IoT as a remote way to access and monitor the water inside the incubator. [6]

2.2.1.1 *S*ummary of the conducted study

S/N	AUTHORS	APPLIED TECHNIQUE	accomplishment	Gaps and remarks
1	Leif Jorgensen [6]	Data are collect through sensor and can be adjusted	-Focuses on fish eggs' life -Dead and infected eggs are removed continuously and automatically from incubator	**Gap:** Doesn't include IoT system **Remarks:** all data should be accessed remotely and controlled when necessary
2	M.S.Chavan1 et.al [11]	big data analytics	Monitor aquaculture in general based on IoT using Raspberry Pi	**Gaps:** doesn't care about fish eggs **Remarks:** eggs' life should be considered as separate to other old fishes
3	Janet et.al [5]	Collect data using sensors	Monitor ponds based on IoT with ARDUINO	**Gaps:** - does not specify type of ARDUINO - targeting all fishes in general not fish eggs -less number of sensors **Remarks:** - There should be a specified type of

				accurate ARDUINO for further implementation - Eggs' life is rigid and most vulnerable to environmental changes than old fished - Various sensors are needed to make system more sensitive
4	Shareef et.al [12]	-Collect data using sensors -Analyze data with logic	A real time monitoring through base station (quick notification)	**Gaps:** - not easy to afford - it cannot process big data - it doesn't focus on particularity of fish eggs' life **Remarks**: in Rwanda fish farmers need a system which is affordable it should be better if other network systems are used (ROLA, WIFI)

Table 2. 1 Summary of the conducted study

2.2.2 Review of literatures

2.2.2.1 Fish Kill Problem

Fish die from a variety of natural causes. Observing a few dead fish in a pond is not uncommon and is no reason for concern unless it continues for several days. When fish die in large numbers, however, there is reason for concern. A common cause of fish kills is oxygen depletion. This condition usually occurs during summer in very fertile ponds as a result of pond turnover or the die-off of an algal bloom. During hot weather most ponds have a layer of water near the bottom that contains little or no dissolved oxygen. When high winds or cold rain cause this water to mix with the upper pond water, oxygen levels often drop low enough to kill fish. Oxygen depletion also occurs when dead algae or other plants decay in the pond after herbicides have been applied to control weeds.[13]

2.3.3.1 Physical aspects of Water Quality in fish pond culture

The composition of water changes with the climatic conditions and how the water is used. The aim of a good pond culture management is to control this composition to yield best results. Fish farmers need to understand both the physical and the chemical components that contribute to good and bad water quality. [14]

2.2.2.3 Water Temperature

Water temperature is one of the critical physical aspects that fish farmers must monitor. Fish are referred to as cold blooded animals because they adopt to the temperature of the water. The water temperature therefore affects the fish level of activity, feeding and reproduction.
Temperature outside the optimum range of the fish might kill or affect the growth of the fish

Temperature also affects the chemical process in water. For instance, during pond treatment when the water is warm, fertilizers dissolve faster, herbicides act quicker, rotenone degrades faster and the rate of oxygen consumption by decaying manure is greater. [14]
The temperature is the driving factor of all processes that happen in the fish pond. It’s not only affecting the development and growth of the plants and other animals in the pond, but also regulates the oxygen level in the water. The

2.2.2.4 Water pH

Water may be acidic, alkaline or neutral. This behavior of water is measure in pH values.

The pH value ranges from 0 to 14, with pH 7 indicating that the water is neutral. Values smaller than 7 indicate acidity while those greater than 7 indicate alkalinity (GOK, 2016).

Figure 2.2 show the pH limits and optimum tolerance for fish. Carbon dioxide plays a major role in determining the PH of water.

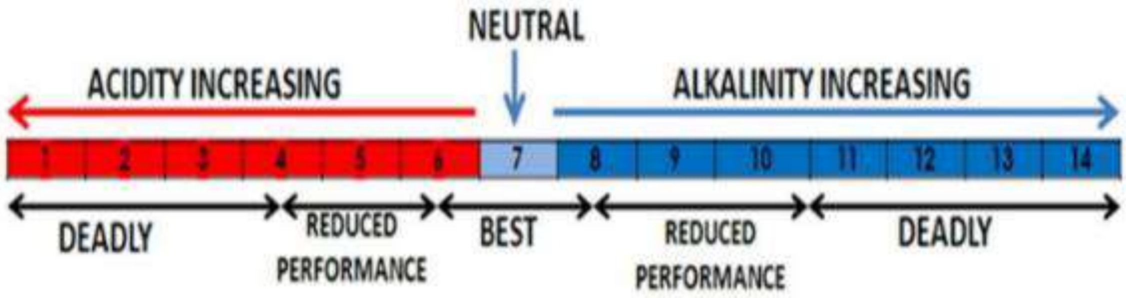

Figure 2. 1 pH ranges showing tolerance limits and optimum range for fish[14]

The aquatic vegetation aids in regulating the PH levels of the water since they utilize carbon dioxide during photosynthesis hence rises the alkalinity levels of the water during the day and lowers during the night Figure 2.10 illustrates the fluctuation in PH of fish pond culture

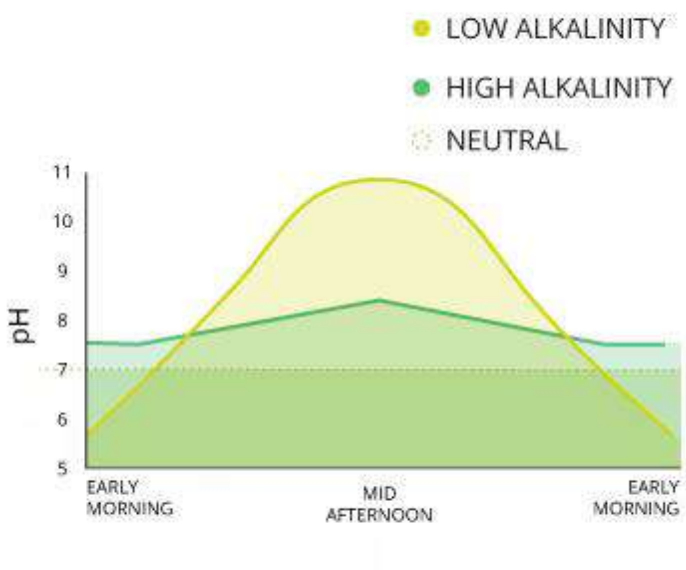

Figure 2. 2 Daily fluctuations of PH in fish pond water[14]

2.2.2.5 Water flow rate

A study has been conducted on the use of high-water water to circulate fish eggs in white cans as a possible way to fight infectious diseases. Higher flow rates of fungal infection and reduced hatching success. Eggs cultured at a 1200 ml/min flow were lifted into the water column and rolled moderately; this flow rate significantly increased the % hatch due to control of fungus. A flow of 1800 ml/min vigorously rolled the eggs and controlled fungus but also resulted in increased egg mortality. It is concluded that the use of water flow to roll eggs controls fungal infections and may reduce, or in some circumstances, eliminate the need for chemical treatment.[15]

2.2.2.6 Artificial incubation of fish eggs

Artificial incubation of fish eggs is a hatchery practice that will increase the economic efficiency of a commercial fish culture operation. Hatching rates and survival will be increased using artificial incubation. Also, removal of the eggs from the parents may increase egg production by shortening the time for another spawning to occur.[1]

2.2.2.7 Sensor-Based IoT System Architecture

A sensor-Based IoT architecture mainly consists of a set of sensors that collect different types of data and transmit them to a gateway that uploads the data to the cloud. From there it can be accessed by users and/or businesses as actionable intelligence. These components can be described as follows: (1) Low Power Smart Sensors/Edge Devices which function as data collectors that seat at the edge of the network hence their name. They gather minute information that is requiring by the intelligent system. They operate on low power which enables them to support wireless installation and communication (2) local Sensor Network which provide various ways in which the sensors can connect edge devices such as bluetooth, Radio frequency and Wifi (3) the Gateway which functions as a bridge between the sensor network and the cloud. It supports advanced data[14]

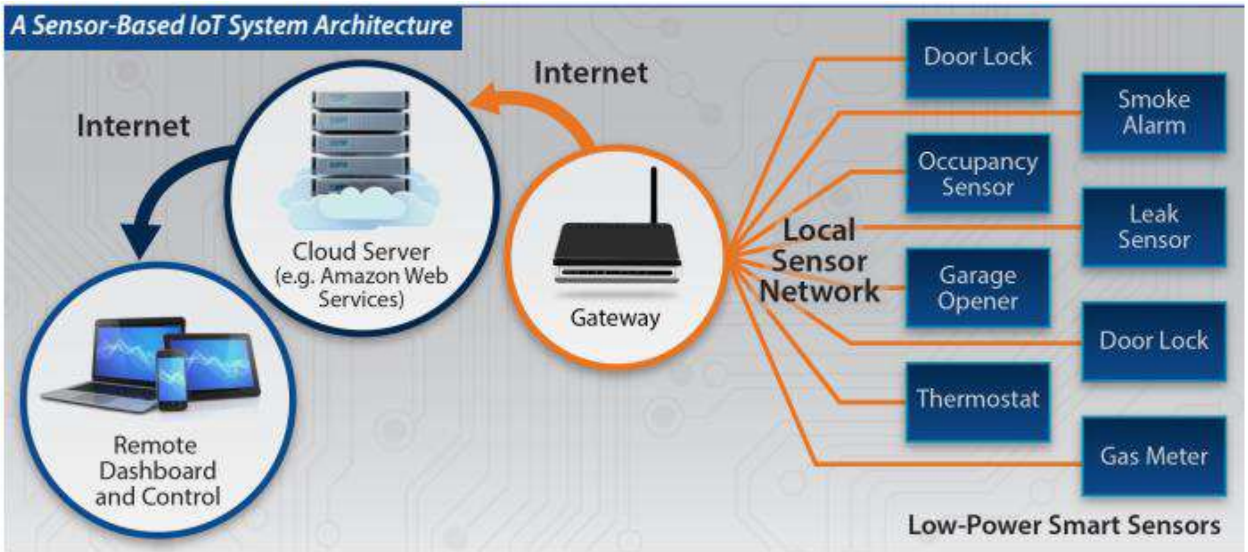

Figure 2. 3 Sensor-Based IoT System Architecture[14]

2.3 Conclusion

In this chapter, an overview of the background of this research area is discussed. Related work and literatures are presented in this chapter. Similarities and contrasting features within conferences and journal papers are also discussed. Some of the technologies and materials that were not considered by some previous researchers are highlighted.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes how the research will be conducted in order to achieve the stated objectives.

It demonstrates the research design and procedures, sample selection, data collection techniques and instruments. The scientific methods for conducting research have been stated in this section as well as the experimental research approach.

3.2 Research Approach and Design of the System

This part describes the overview of the research approaches and the steps involved in system development from the step of gathering the ideas to the final step of prototype and getting result.

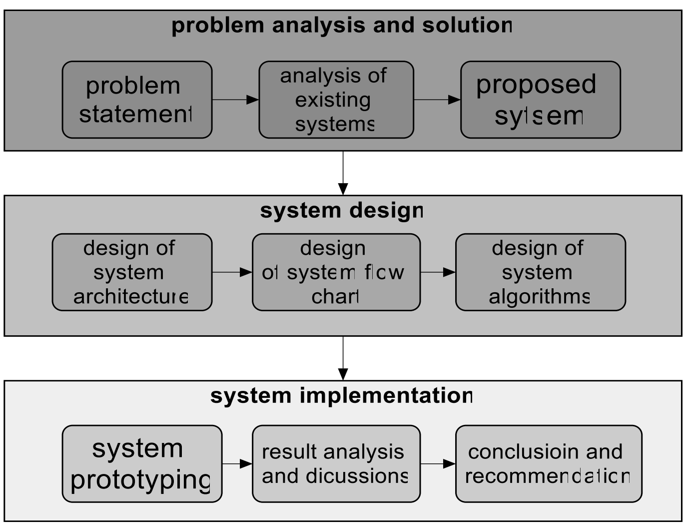

Figure 3. 1 Research Approach

The development approach of this research thesis complies with two stages:

- The algorithm and flowcharts design approach
- Prototyping approach

In this research thesis, the existing systems are analysed and a new system used sensors and actuators were developed.

3.2.1 Application Development Methodology

The study used a fast-track method that was considered good because of its approach to development because it also provides fast systems at low prices especially in time constraints projects. This approach was appropriate for our study due to the limited time in application development. The methodology includes the role of the users in the development process required by the need to assess the outcomes of each phase.[16]

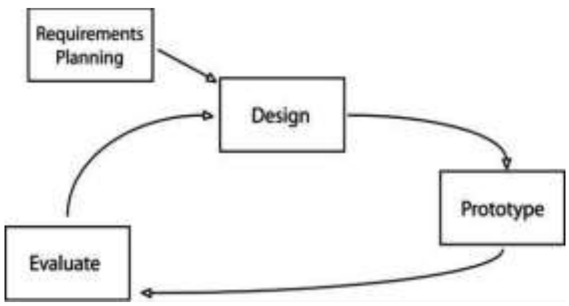

Figure 3. 2 Prototyping Model [16]

Rapid Application Methodology (Córdova et al., 2016)

The methodology was included in stage II as depicted in figure 3.1. Different data collection instruments and rationale for their selection are in section the requirements planning stage entailed gathering information on what the model should contain and how the model is supposed to function. Secondary data was used to determine the water quality and its flow rate aspects that require monitoring. Interviewing the operators of the fish ponds and egg incubators also provided information on what should be included in the model. After gathering the design details, the researcher used software and hardware tools described in chapter five to develop the model incorporating the user design suggestions. The model would then periodically evaluate by the intended users to check whether the modules were functioning as desired.

3.2.2 Data collection instruments

This study used primary and secondary information. The information provided the basis for the development of the various components of the application. The techniques included are:

I. **Literature review** from many sources such as; thesis, government report, conference papers, and journals covered a large portion of the published information. The main sources of information on the quality of water, the barriers to water quality monitoring, and the deficiencies in the current architectures used in monitoring water quality. And then, ways of developing fish egg incubators were properly provided. In summary, they provided legitimate information about fish farming.

II. **Qualitative interview:** this is a type of interview where the interviewer has no specific pre-set question that was to be asked in a particular order. The respondent does most of the talking. These interviews were used during site visits and were used to gather in-depth insights into how water quality and its flow rate inside the incubator are monitored.

3.3 Proposed system requirements

3.3.1 Functional Requirements

In order to monitor water parameters the following functional requirements should be in place

- Sense water parameters through the sensors
- Send sensed data to cloud for storage
- Analyse and visualise data using GRAFANA

3.3.2 Non Functional Requirements

Performance: Based on its hardware, network, software, stability, startup, and storage

Availability: This system will be activated every time.

Reliability: This product will meet desired performance standards and gives output for a desired time duration in certain environmental conditions.

Scalability: many sensor nodes will be enrolled in the deployment

Usability: Anyone with ICT knowledge can use this system

Recoverability: When something is wrong in the system, it is easily recoverable

3.3.3 Hardware and Software requirements

Sensors and actuators requirements Specifications

Sensor is a device that when exposed to a physical phenomenon (temperature, displacement, force, etc) produces a proportional output signal (electrical, mechanical, magnetic, etc) while an Actuator is a component of a machine that is responsible for moving or controlling a mechanism or system. Sensors and actuators are two critical components of every closed loop control system. The controller accepts the information from the sensing unit, makes decisions based on the control algorithm, and outputs commands to the actuating unit. [17]

The following are specifications of sensors and actuators used in this research:

- ✔ pH Sensor Module Agricultural with power supply 5-10V, Measuring range 4-10Ph and Resolution of 0.1pH.
- ✔ water flow sensor with Op range -4^{o} C-85^{o}C, accuracy of ±1^{o}C ,7mA,3.5V-20V
- ✔ DS18B20 Waterproof Digital Temperature sensor, 3V/5V, 2.5Ma and sampling period of 1second

3.3.3.1 Sensors

- DS18B20 Waterproof Digital Temperature sensor

This Maxim-made item is a digital thermo probe or sensor that employs DALLAS DS18B20. Its unique 1-wire interface makes it easy to communicate with devices. It can converts temperature to a 12-bit digital word in 750ms (max). Besides, it can measures temperatures from -55°C to +125°C (-67Fto +257F). In addition, this thermo probe doesn't require any external power supply since it draws power from data line. Last but not least, like other common thermo probe, its stainless steel probe head makes it suitable for any wet or harsh environment. This sensor is mounted on NODE MCU and is used for sensing the water temperature from time to time.[18]

Figure 3. 3 DS18B20 Waterproof Digital Temperature sensor[17]

- Water flow sensor

Flow sensing is relatively a difficult task. The fluid medium can be liquid, gas, or a mixture of the two. Furthermore, the flow could be laminar or turbulent and can be a time-varying phenomenon. The venturi meter and orifice plate restrict the flow and use the pressure difference to determine the flow rate. The pitot tube pressure probe is another popular method of measuring flow rate. When positioned against the flow, they measure the total and static pressures.[17] This sensor is mounted on NODE MCU and is used for sensing the water flow rate from time to time

Figure 3. 4 Water flow sensor[17]

- pH sensor

This pH Sensor can be used for any lab or demonstration that can be done with a traditional pH meter, including: acid-base titrations, monitoring pH in an aquarium, and investigating the water quality of streams and lakes.[19] This sensor is mounted on NODE MCU and is used for sensing the water pH from time to time.

Figure 3. 5 pH sensor [19]

3.3.1.2 Gateway and Communication Technology Requirements

An Internet of Things gateway is a physical device or software program that serves as the connection point between the cloud and controllers, sensors and intelligent devices. All data moving to the cloud or vice versa, goes through the gateway, which can be either a dedicated hardware appliance or software program. The IoT gateway provides a complex representation of the instances. The main tasks the IoT gateway perform are: Data forwarding, Gateway management, Device management, Data analysis and Diagnostics [20].

In this project, water monitoring will be done with **ESP8266 WiFi Module** as a Gateway and **WiFi** as Communication Technology.

The ESP8266 WiFi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, meaning, you can simply hook this up to your Arduino device and get about as much WiFi-ability as a WiFi Shield offers.

This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. The following figure illustrates the ESP8266 12-E chip pinout.

- ESP8266 NodeMCU

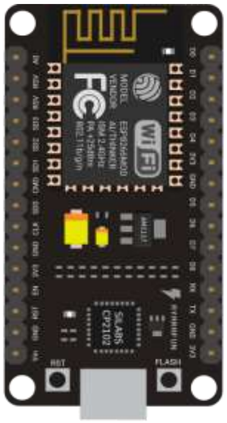

Figure 3. 6 ESP8266 NodeMCU [21]

3.3.3.2 Cloud and IoT Analytics Platform requirements

In the simplest terms, cloud computing means storing and accessing data and programs over the internet instead of your computer's hard drive. The cloud is also not about having a dedicated network attached storage hardware or server in residence, it's as a service. Cloud computing is intelligent. With all the various data stored on the computers in a cloud, data mining and analysis are necessary to access that information in an intelligent manner [22]. Node-RED is a visual tool for wiring the Internet of Things developed by IBM Emerging Technology and theopen source community. Using Node-RED, developers wire up input, output and processing nodes to create flows to process data, control things, or send alerts. It works by allowing you to wire up web services or custom "nodes" to each other, or to things, to do things like:[23]

- Send an email on a rainy weather forecast.
- Push sensor data to services like Twitter.
- Perform complex analysis on data with ease

Grafana is Graphite Webapp. Graphite is an open-source monitoring tool for storing and viewingtime series data.Graphite consists of 3 software components:[24]

- Carbonl
- Whisperl
- Graphite Webapp (Grafana)

3.3.1.4 Microcontroller Requirements and Specifications

ARDUINO UNO pin type definitions									
Resets arduino sketch on board	3.3 volts in and out	5 volts in and out	ground	Voltage in for sources over 7V (9V-12V)	Analog inputs, can also be used as digital	Serial comm. Receive and transmit	Input or output, HIGH, or LOW	Digital pins with output option of PMW	External reference voltage used for analog

Table 3. 1 Microcontroller Requirements and Specifications[25]

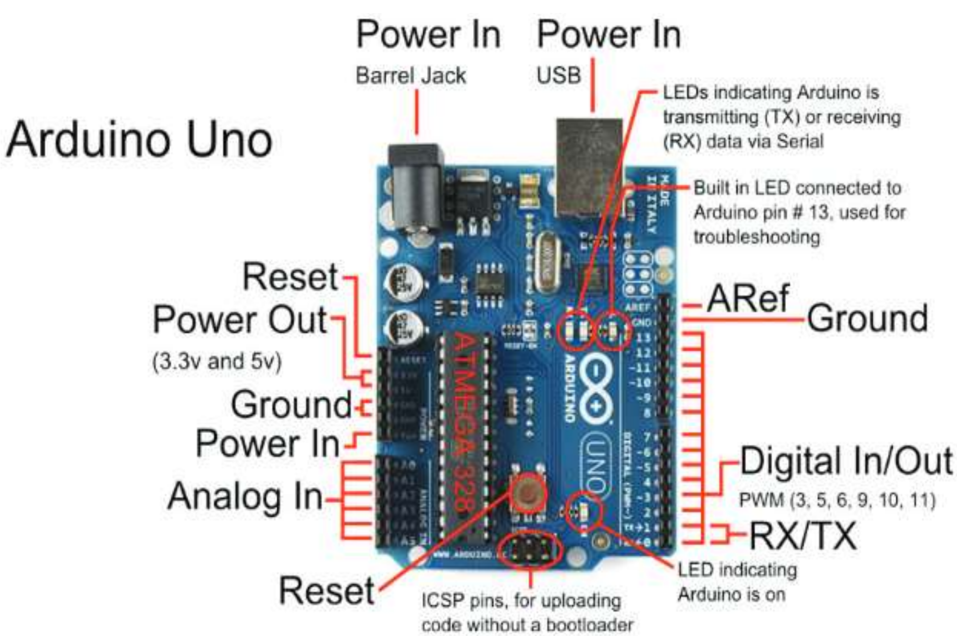

Figure 3. 7 ARDUINO UNO pinout[25]

ARDUINO UNO Technical specifications [25]

microcontroller	Atmega328P – 8bit AVR family microcontroller
Operating voltage	5 V
Recommended input voltage	7-12 V
Input voltage limit	6-20V
Analog input pins	6(A0-A5)
Digital I/O Pins	14 (out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3 V Pin	50 mA
Flash memory	32 KB (0.5 KB is used for Boot loader)
SRAM	2 KB
EEPROM	1 KB
Frequency (clock speed)	16 MHZ

Table 3. 2 *ARDUINO UNO Technical specifications*[25]

3.3.1.5 Integrated Development Environment Requirements (Arduino IDE)

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards. In this research Arduino 1.8 version was used.[26]

3.3.1.6 Node-Red Development Tool

Node-RED is an open source flow-based development tool for the integration of IoT hardware devices, APIs (Application Programming Interfaces) and online services developed by IBM Emerging Technology. Node-RED is a free JavaScript-based tool, built on Node.js platform, which provides a visual browser-based flow editor. The system contains nodes that are represented by appropriate icons. It can operate in two ways: drag, drop and wire up nodes, or import JavaScript code.[27]

Node-Red, developed by IBM helps in combining the hardware, API and other online services in a smart way. It is a flow editor based on the browser. It can be installed in a Linux Platform. It comprises of two components as explained below.

A. Nodes

Nodes are written in node.js. It can be easily installed from the Node-Red library.

B. Flows

Node-Red Flow Diagrams are created by integrating various Nodes that are configured and are stored using JSON.[14]

3.4 Design process

Hardware/software codesign is the process of designing computing systems consisting of both hardware and software components. It is by nature a cooperative and concurrent design process as decisions to use specific hardware components for selected sections of an application must be taken with a global view of the system. Although the main tasks of hardware/software codesign involve describing the system and exploring the best possible architectures to implement such a system as illustrated in Fig. 8.4, often the target architecture is fixed with the possible exception of the reconfigurable hardware component when present.[25]

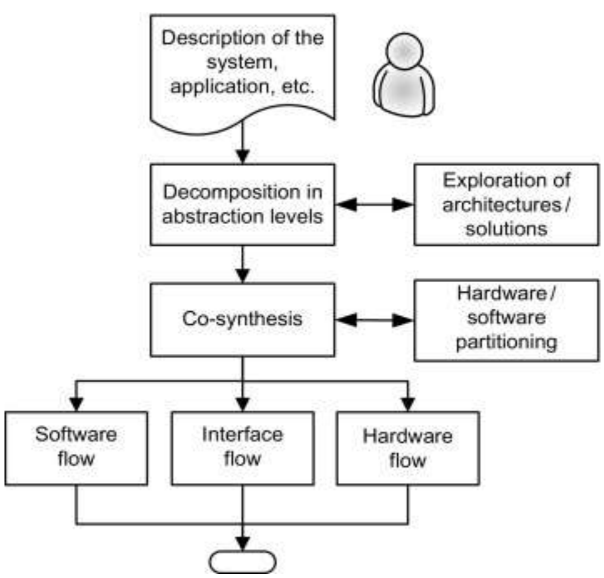

Figure 3. 8 Hardware/software codesign main tasks[25]

3.5 Existing products and comparison

TECHNOLOGY	**Eruvaka Technologies**	**E-fishery Technologies**	**Comparison with the proposed system**
Products	- PondGuard - PondMother - ShrimpTalk - PONDLOGS	- eFisheryFeeder Ikan - eFisheryFeeder Udang - **eFisheryFresh** - **eFisheryFeed dan** - **eFisheryFund**	
Description	Measures only certain water temperature and dissolved oxygen and sends the reading to the monitoring unit and sends SMS to the farmers to provide alert notifications to them.	Provide real time feeding to the fishes when the time is set so as to avoid wastages due to improper fish feeding.	Monitor water quality inside fish egg incubator by reading pH level and flow rate, controlling remotely water temperature and send all recorded data to the cloud.
Sensors	Temperature, pH, and dissolved oxygen	Sensor to detect the fishes	pH, Temperature, Water Flow sensor
Cloud platform	Yes	No	Yes
Pictures			-
Comparison with the proposed system	The proposed system remotely controls water temperature and measures the water flow rate inside the fish eggs incubator. The full details of this system design and implementation is explained in the next chapter.		

Table 3. 3 Comparison of existing products with proposed system

3.6 Conclusion

This methodology chapter covers the approach to perform the research, the methods of data collection, its analysis, and the processes to be undertaken during prototyping. The analysis and design of the proposed system will be explained in Chapter 4.

CHAPTER 4 SYSTEM ANALYSIS AND DESIGN

4.1 Introduction

This chapter introduces the purpose of automated fish egg incubator. Also, systems analysis and design are used to analyse, design and implement a prototype. This chapter illustrates how farmers will interact with the system and shows the process of operation of the system designed to collect data on water quality such as temperature, pH level, and water flow rate inside the incubator.

4.2 System Model

This project model discusses monitoring some of the water parameters that could have a direct impact on the health of fish eggs, helping the aquaculture board to monitor and conduct research based on real-time data given by this project.

This automated fish egg incubator is formed of an intelligent control dashboard by node-red and GRAFANA and will be accessed through the internet.

This system must be deployed near the fish pond to collect data and send them to local storage or cloud then to breeders based on the location of the pond. The figure below shows the proposed system.

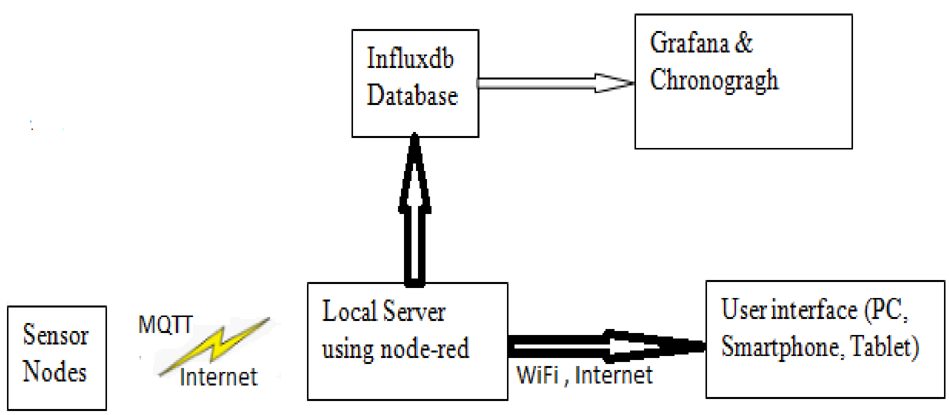

Figure 4. 1 System and Software design architecture

4.3 Proposed System and Algorithm Design

4.3.1 Architecture Overview

Automated fish egg incubator architecture gives an overview of physical objects, sensors, cloud services, actuators, and IoT Protocols.

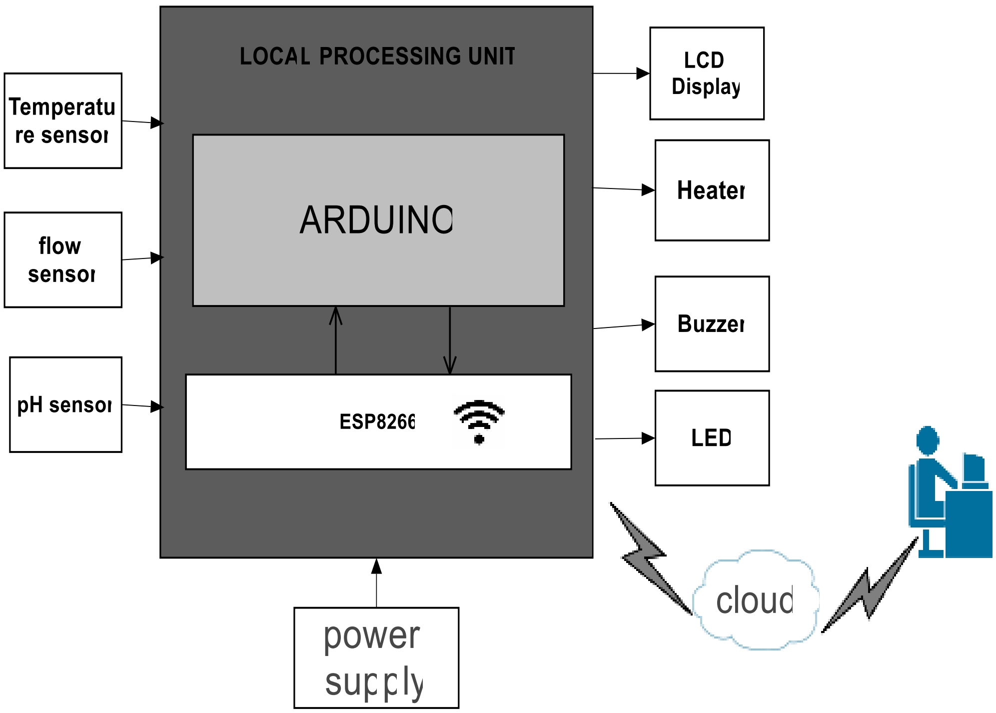

Figure 4. 2 Proposed system architecture

4.3.2 Flowcharts Design

The following diagram is a flowchart in which the whole system work process is well described from the field of information to the end-users.

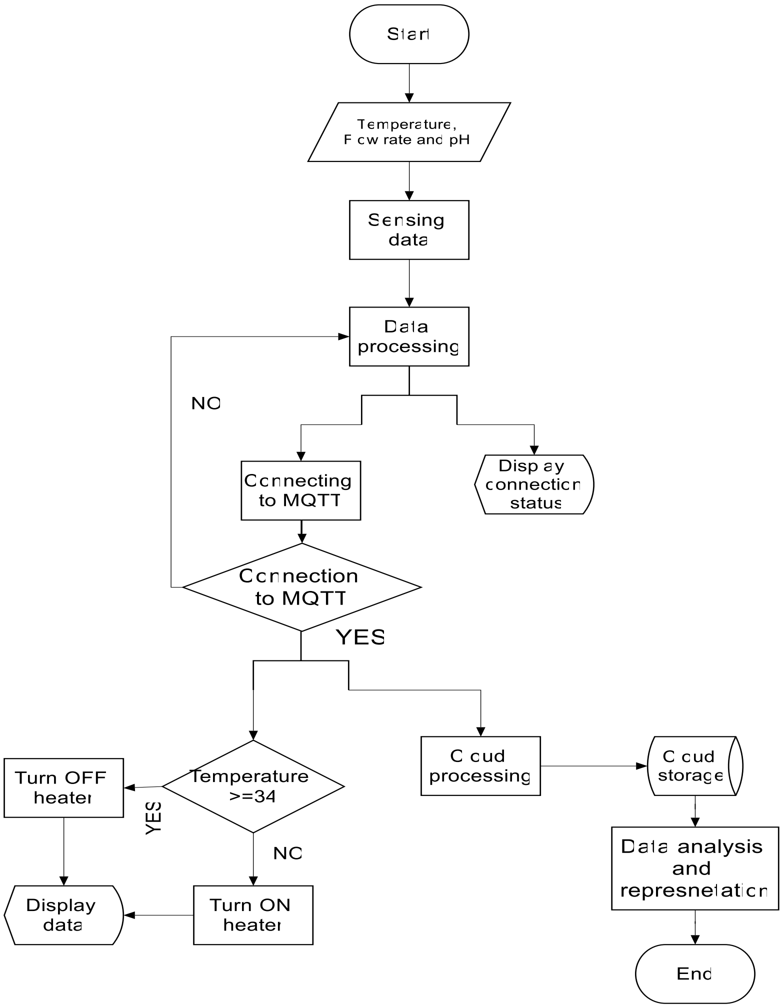

Figure 4. 3 System Flowcharts

4.3.3 Circuit Design

Automated fish egg incubator will be made of the following circuit which consists of sensors connected on microcontroller and a WiFi Module ESP8266 as shown in figure 11.

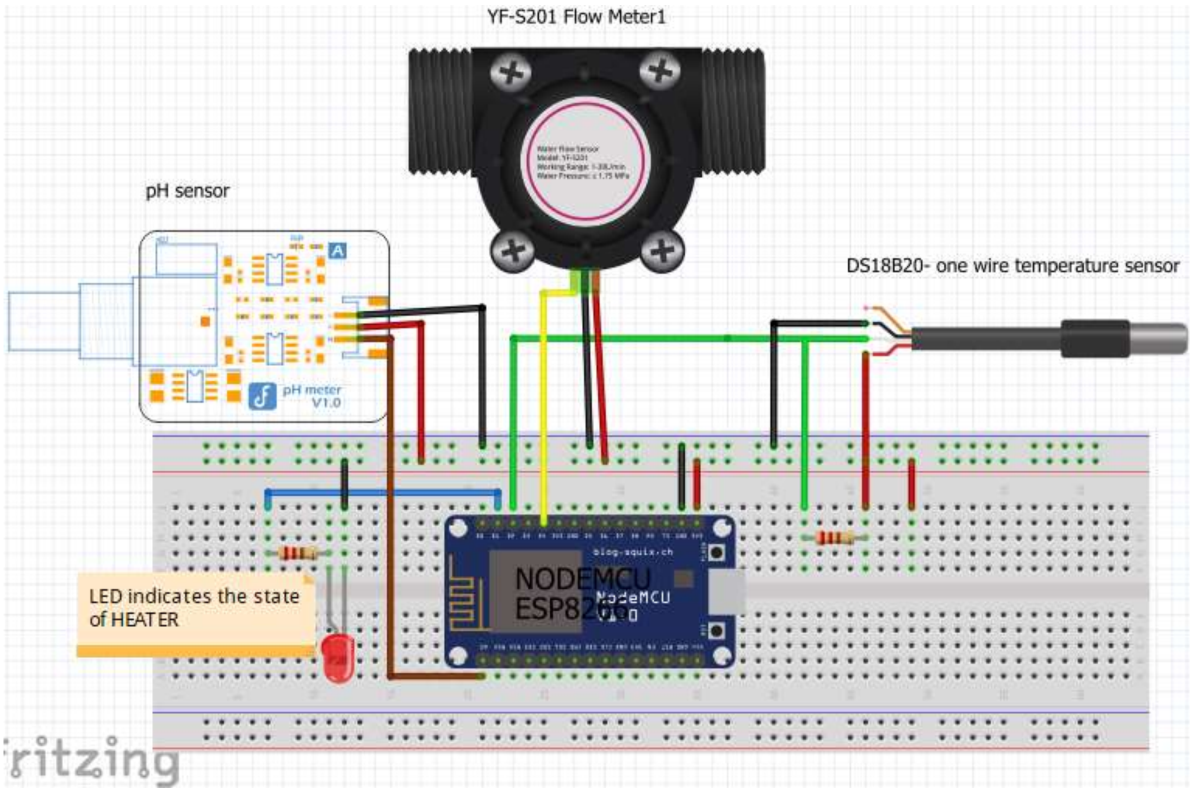

Figure 4. 4 Circuit Design

Components specifications

Item	**Model**
MCU	node mcu
Wifi module	esp 8266
Led	red
Temperature sensor	ds18b20 waterproof
Water flow sensor	YF-S201
resistor	1K
ph sensor	SEN0169
Wire	Jumpers

Table 4. 1Components specifications

4.3.4 Server dashboard construction

The following diagram is a nod red flow control in which is composed of MQTT nodes, database, and display

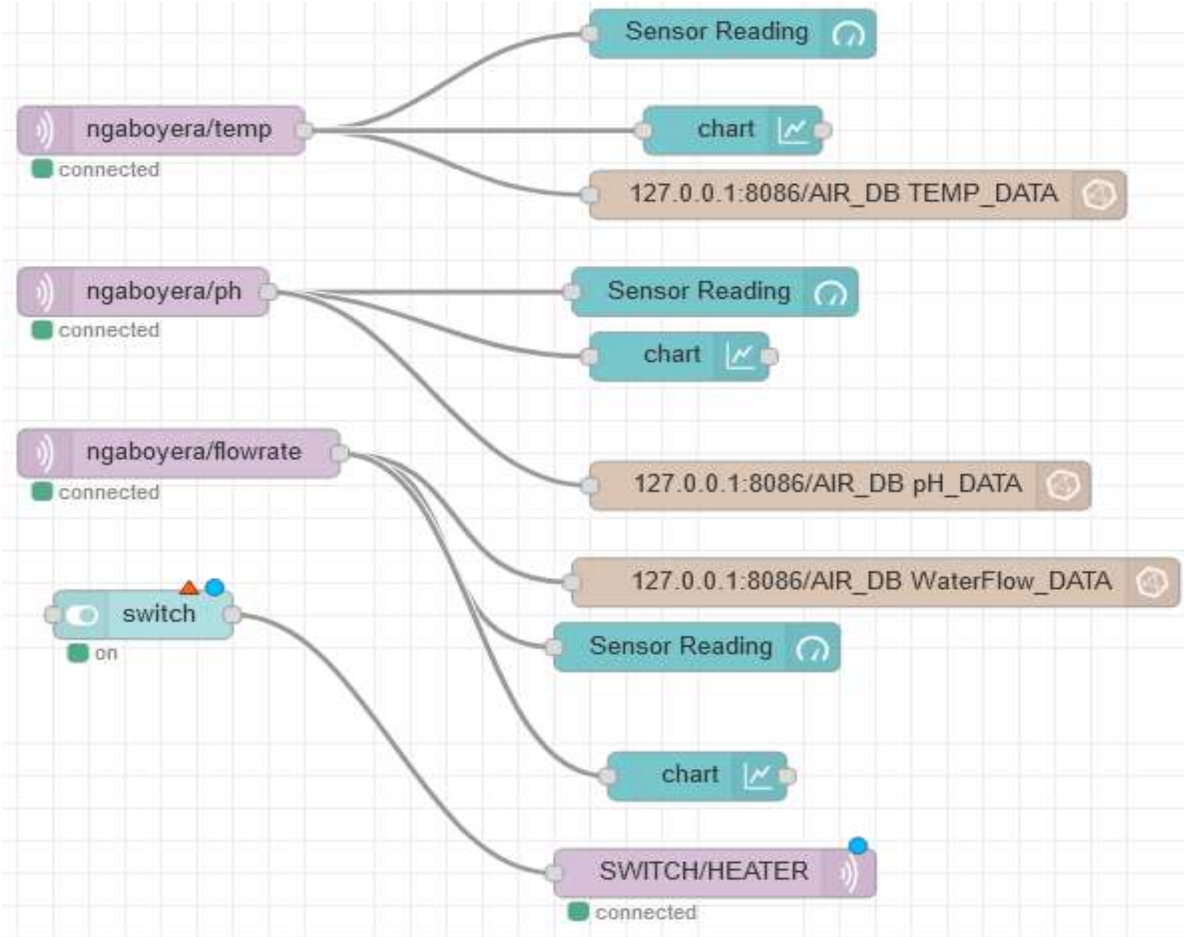

Figure 4. 5 Node red flow control

CHAPTER 5   RESULTS AND ANALYSIS

5.1 Introduction

In this chapter, the performance of an automated fish eggs incubator was tested, where data are sensed by the sensor node and sent to the cloud, from cloud to the database and visualized on the dashboard in different forms. Different data such as temperature, pH, and flow rate as water parameters inside the incubator are well analysed.

5.2 Evaluation of Temperature

To evaluate temperature, a DS18B20 Waterproof Digital Temperature sensor was used. The figure 5.1-3 represents respectively current temperature, and if is any changes made data updated every 15seconds and being represented in numbers as shown in fig 5.1. With real-time temperature, data provided by node-red, breeders can adopt the given situation and take additional policy practices to minimize risks from fish eggs. Therefore, accurate information regarding water quality is important so that fish eggs' life can be monitored.

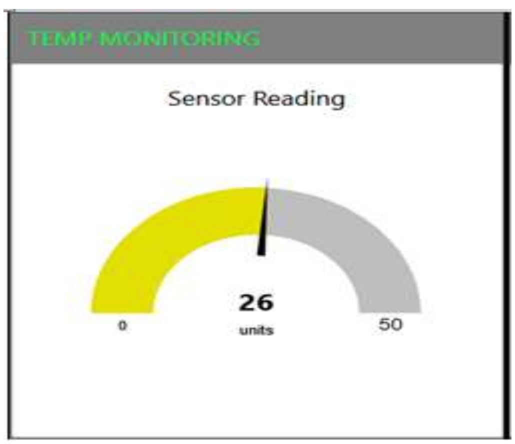

Figure 5. 1 Readings temperature on dashboard

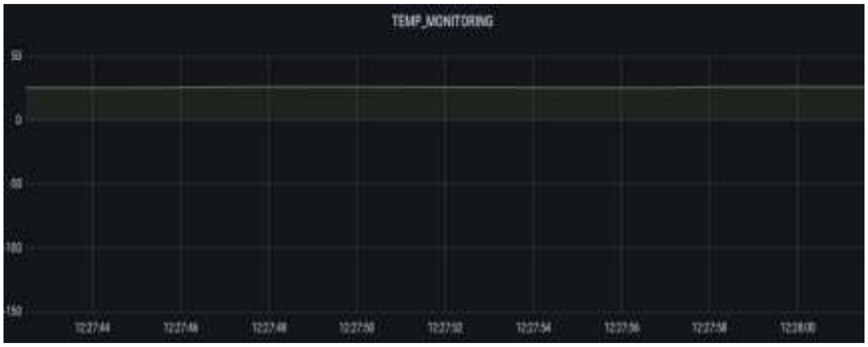

Figure 5. 2 temperature representation in grafana

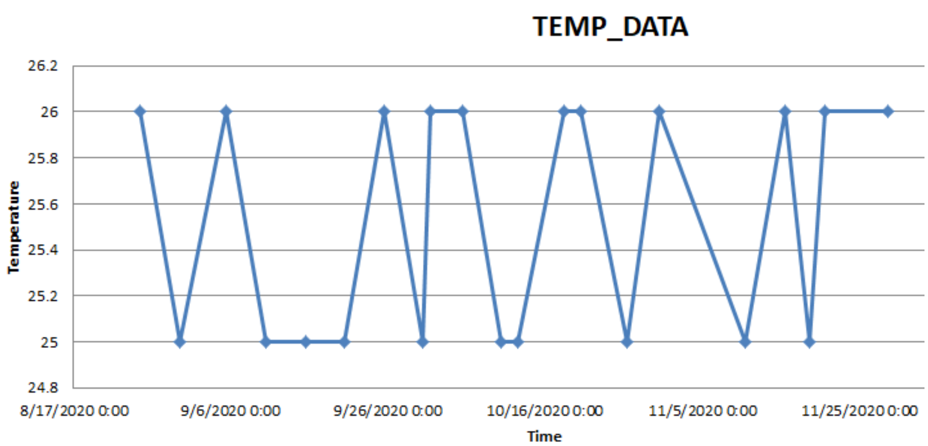

Figure 5. 3 temperature representation in excel

5.3 Evaluation of pH

To evaluate water pH, pH sensor was used. The figure 5.4-6 represents respectively current pH level, and if is any changes made data updated every 10 seconds and being represented in numbers as shown in fig 5.4. With real-time pH data provided by node-red, breeders can adopt the given situation and take additional policy practices to minimize risks from fish eggs. Therefore, accurate information regarding water quality is important so that fish eggs' life can be monitored.

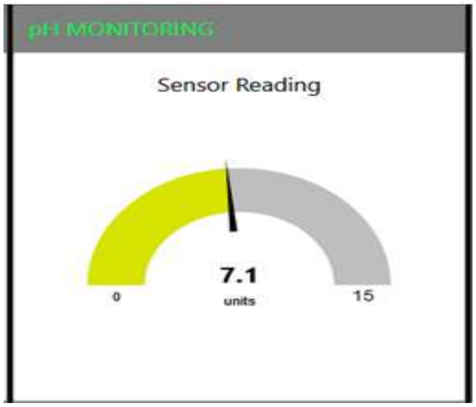

Figure 5. 4 Readings pH on dashboard

Figure 5. 5 pH in grafana

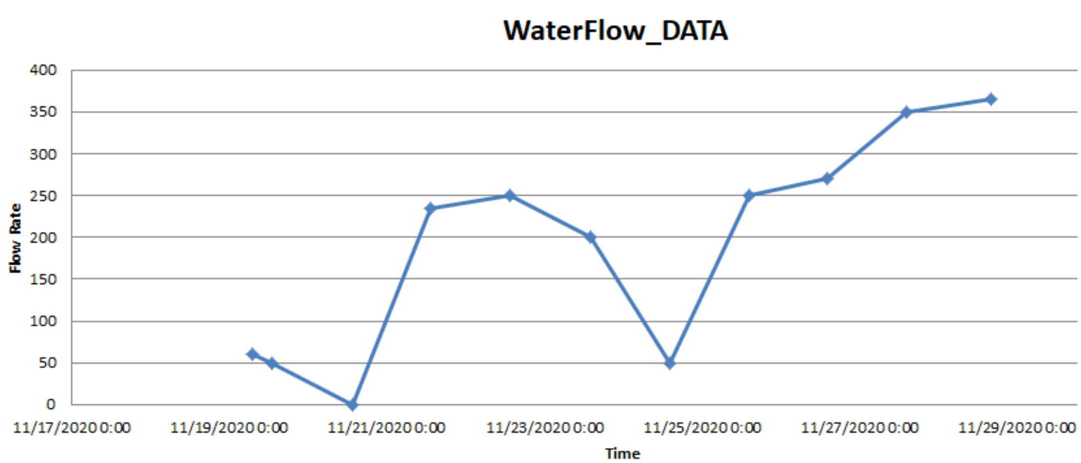

Figure 5. 6 pH in excel

5.4 Evaluation of Water Flow Rate

To evaluate water flow rate, The figure 5.7-9 represent respectively current water flow rate and if is any changes made data updated every 10 seconds and being represented in numbers as shown in fig 5.1. With real-time flow rate data provided by node-red, breeders can adopt the given situation and take additional policy practices to minimize risks from fish eggs. Therefore, accurate information regarding water quality is important so that fish eggs' life can be monitored.

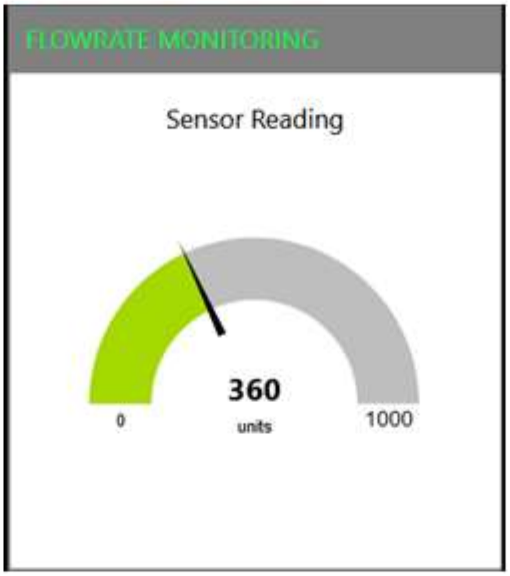

Figure 5. 7 Readings flow rate on dashboard

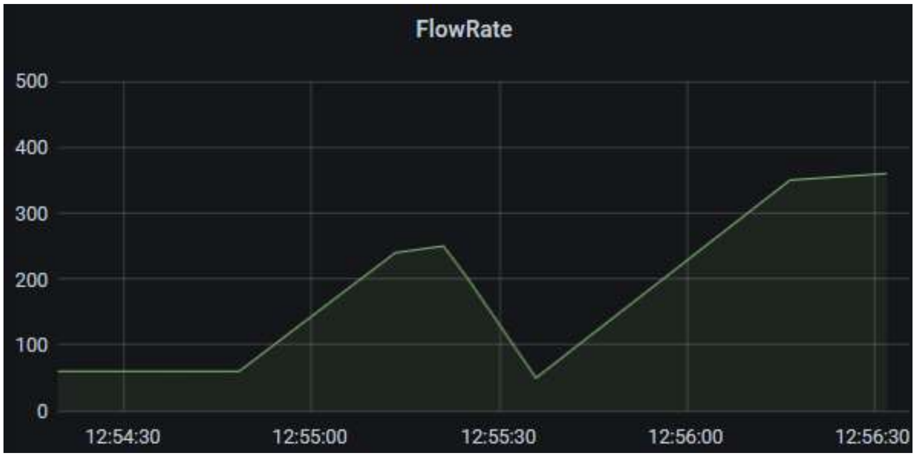

Figure 5. 8 Flow rate in grafana

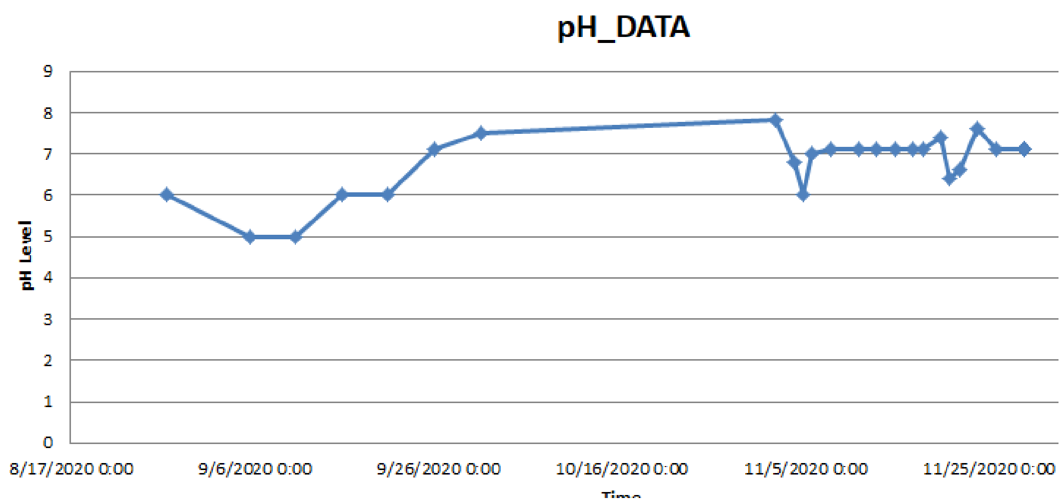

Figure 5. 9 Flow rate in excel

To meet the objective of this project, the following figure shows the control of heater to maintain temperature level inside the incubator

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

An automated fish egg incubator collects data from sensors that contain water parameters and pushes them to the cloud through Wi Fi and MQTT protocol and stored in the cloud. Through influx dB, data can be analysed and presented directly using GRAFANA or exported as a CSV file and into excel. Wherever internet access reaches, the user can access current data from the system by opening the provided link. This system will help people from different sectors such as fish farmers and all other entities private and governmental in charge of aquacultures in the increase of fish production and research for the future of aquaculture. This study will also help breeders to evaluate instantly their farm so easily and take measures to produce a lot of production hence an increase in revenue and food production and thus contributing to the production growth in Rwanda.

The study will also help fish farmers to assess easily their ponds and take measures to increase their productivity through increased fish production and play a role in boosting its production in Rwanda and other countries that will use this system**.**

6.2 Recommendations and future works

Due to the rapid development of technology, and the increase in the number of fish farmers, it will be necessary to raise fish at home. The problem will be an insufficient number of small fishes to grow where people will take advantage of using fish eggs incubators to get more fries. Although the project has tried to simplify the process of remotely monitoring fish eggs' life, there is still a lack of linking it to the method of counting eggs inside the incubator and determine and eliminate dead eggs. As future direction, there should also be in place an artificial intelligence to count the number of fish eggs to predict their rate of death and the change in weight to predict the rate of their growth.

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