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IOT Monitoring Systems in Fish Farming Case Study:" University of Rwanda Fish Farming and Research Station (Ur-FFRs)"

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Abstract

Purpose: Fish farming refers to the farming of aquatic organisms such as fish. It involves cultivating freshwater and saltwater populations under controlled conditions. The purpose of this research is to provide a solution to the fish farmer by developing an application that would be easy to monitor water quality during the fish farming process. This will help the fish farmers to intervene timely, and therefore increase their production. The design and implementation of IoT Monitoring Systems in Fish farming helps to observe the farming system remotely by using different sensors for the water parameters. The research focused on developing a system for real time monitoring of culture tank water quality as a proof of concept and testing the basic functionalities of the system.

Methodology: The research adopted the Rapid application methodology, which was deemed best due to its iterative approach to applications development as it also delivers systems faster at a lower cost in time-constrained projects. This methodology was suitable for our research given the time constraints in developing the application. Secondary data was used to determine the water quality aspects that require monitoring. Interviewing the operators of the culture tank also provided information on what should be incorporated in the model. by developing an application that would be easy to monitor water quality during the fish farming process. The application dashboard is the graphical user interface that the users shall use to interact with application components.

Findings: This research proposes a solution, which is a real-time culture tank (hatchery) water quality-monitoring model, which utilizes a web application that shall be adopted by the staff of the University of Rwanda Fish Farming and Research Station and farmers. The model utilizes the IoT concept, which enables information gathering about water quality through the corresponding sensors. The status of the water quality aspects shall then be relayed on a real-time basis through a cloud platform. The farmer can then act based on the information provided, or the model can act on the farmer's behalf based on predetermined actions. The model's data can be extracted and analysed in a variety of different ways.

Recommendation: This research contributed in developing a technological solution for real time monitoring water quality aspects of culture tank (hatchery) that can be adopted by fish farmers in Rwasave Fish Farming and Research Station by providing them with real time data whenever they are within or away from the culture tank (hatchery) site. This helps to eliminate or minimize the risk of losing fish and wastages due late interventions.it was validated by supervisors of the project.

Keywords: *IOT, Fish Farming, Monitoring System*

1.0 INTRODUCTION

Rwanda is a country characterized by subsistence agriculture and prevalence of nutritional deficiencies. For example, across the country, 37% of the total population consumes fewer calories than the minimum requirement, and 64% of the population is deficient in protein intake. In Rwanda, fishing is conducted by cooperatives and associations; mainly in the lakes Cyohoha, Kivu, and Mugesera. Owing to inadequate restocking of fish in the lakes, however, the output is quite low. Current efforts to develop the fishery industry include encouraging and supporting fish farming by means of rehabilitating the old, and opening up new fishponds. With the increasing demand for fish as a source of food, the management techniques in systems with high densities of fish and high feeding rates has been of great concern in making intensive and semi-intensive fish farming viable (Mahalik & Kim,2014).

In Rwanda, fish farming is practice in different places. One of the major fish farming and research station was established at Rwasave in 1982 by the National University of Rwanda and currently produces fish for research and commercial purposes. University of Rwanda Fish Farming and Research Station (RWASAVE) is located in the Ngoma Sector approximately 3 km from the University of Rwanda, Huye Campus. It is approximately 2 km from Butare city, and about 130 km south from the capital city of Kigali. The UR-FFRS station is located at 02º 36'09. 5'' latitude South, and 29° 45'25'' longitude East. About the station is elevated at 1,625 m above sea level. Currently, research station manages 106 ponds and one Recirculating Fish farming System (hatchery), which are used in the research and production process.

The supply canal runs 2.5 km from a small dam in the river to the station. The canal passes through some cultivated marshlands where there are some exchanges with standing water. The types of fish produced at the station are Tilapia Nilotica and Clarias gariepinus. At the University of Rwanda Fish Farming and Research Station (RWASAVE) the water from culture tank are routed directly to the Rwasave river except for some experimental ponds where, from fish pond water is poured into rice plots and from the rice plots to the Rwasave River. The main challenge the University of Rwanda Fish Farming and Research Station (RWASAVE) has is they do not have a real-time monitoring system that knows the status of water quality in the culture tank, when they need to know the status they took a sample of every culture tank and they took in the laboratory to measure water quality.

All those activities are manual and they take time to do it. The proposed system continuously monitors the water quality parameter using sensors; the detected information is conveyed to the aqua-farmer mobile via the cloud. Accordingly, actions will be taken in time to reduce the losses and improve productivity. This methodology can facilitate the aqua-farmers for the precise and reliable observance of water parameters; the fact that manual testing will take longer and water quality parameters could change with time it additionally takes proactive measures before any harm was done. Although the primary cost is high, there will be no extra expense and maintenance once it is installed. Thus, the framework implemented will reach the farmers for reducing the harm from climatic changes and confirms growth and health for aquatic life. This improves productivity, helps in improving foreign trade, and increases the GDP of the country. Data generated by the system would contribute to further studies or/and future researches.

Problem Statement

The University of Rwanda Fish Farming and Research Station (RWASAVE) rely on traditional water quality monitoring methods such as note writing; taking a sample of each culture tank and observation, which are prone to errors. The big challenge faced Fish Farming and Research Station has to visit many times (every two hours) in a day to check the water quality of the culture tank (hatchery), But this manual testing is time-consuming and also gives inappropriate results as parameters for measuring water quality change continuously. It will be better if automatic monitoring can be done somehow. So modern technology should be brought to fish farming to overcome this problem. The proposed methodology in this work will assist fish farmers in employing IoTs to monitor culture tank water quality. Sensor and internet technology paired with a user-friendly interaction interface via a smartphone or web interface to allow real-time monitoring of fish tanks could make a substantial contribution to decreasing the risk of losses and improving efficiency.

2.0 LITERATURE REVIEW

This chapter presents a discussion on the challenges faced by farmers in monitoring the water quality, the key parameters used in fish farming monitoring. The various application architectures used for the monitoring were reviewed and used as a basis for developing the model that was an improvement of the already existing models. A few papers in literature overview canters around how the aquatic life will impact because of progress in water quality parameters and how IoT is utilized to overcome the issue.

According to (FAO, 2017) statistics 1,580 tonnes of fish have been produced by fish farming in 2016 in Rwanda. In this survey, 37 small-scale pond-based commercial farms contributed 218 tonnes from 616 ponds (surface: 65.57 ha) in 2017. Small-scale commercial cage farms contributed 168 tonnes to fish farming production from 186 cages (volume: 6,014 m^3). Five out of seven registered medium-scale commercial cage farms contributed 730 tonnes from 114 cages (17,304 m^3). This reported production concerns only farms above 10,000 m^2 of ponds or 100 m^3 of cages in one location and does not include production from small farms nor from subsistence farming.

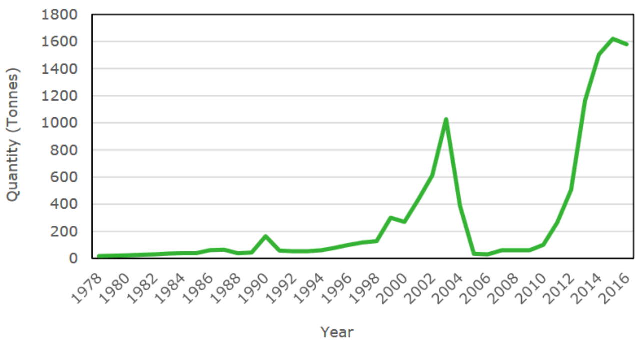

Figure 1 : Fish Farming Production in Rwanda

Source (FAO,2017)

Fish kill is an event where there is a sudden appearance of dead fish in the fishponds.

According to (Faruk et al 2004) said that the common cause of major fish kills is low dissolved oxygen in the water. A combination of environmental factors results in low amounts of oxygen. During the night there is competition for oxygen between the plants and the fish, which use oxygen for respiration and bacteria which use oxygen for decomposing organic material.

According to (kim et al,2015), most fish kills are because of oxygen depletion that occur during the night in hot weather conditions. They further noted that, the fish kills occur during dawn due to (a) the die-off of a large algae bloom, (b) the decay of waterweeds after treatment with a herbicide, (b) the turnover of oxygen-poor bottom waters following a thunderstorm, (c) the runoff of livestock waste and other organics after a heavy rain.

Consequently, they emphasized on the need for constant monitoring of the water quality since conditions of the pond might change rapidly (within hours). Minor fish kills where there is a small number of dead fish per day, are caused by poor water quality.

The only remedy for fish kills is maintaining good water quality. Fish live in water therefore it is obvious that the water quality must be good for fish to thrive. Most fish farmer depend on natural sources of water which are not reliable as they dry up or reduce level during drought (shitote et al. 2012).

According to Boyd and Lichtkoppler (1979), There are key water properties that need to be monitored and regulated so as maintain an ideal environment for the fish. The main threats to fish farming as identified by. It is important for farmers to understand that different species have different and specific range of water quality aspects (temperature, PH oxygen concentration, salinity, hardness, etc.)

Cerny & Casto (2017) developed a fish farming system that uses three parameters namely: pH, temperature, and flow rate. These three parameters' correlation were computed, and experiments showed that "the pH has inversely proportional to temperature, but flow rate has no effect on the pH and temperature."

Ujwala.T et al, (2020) developed Automated Monitoring and Control System for Shrimp Farms Based on Embedded System and Wireless Sensor Network which is a low-cost, versatile and prototype system it was developed to elaborate a commercial product in fish farming. A distributed system was implemented using ZigBee, GSM, Cloud, MSP430 and LabVIEW technologies. This system monitors three variables that are pH, Oxygen and Temperature in two shrimp farms. It is concluded that the implemented system is scalable, intuitive and low cost. We recommend adding more sensors to obtain more information on the state of the water quality and to be able to carry out a more complete analysis and give more reliability to the system through validation with commercial measurement instruments.

Espinosa.C et al, (2016) developed A Mobile Platform for Remote Monitoring of Water Quality on Live Fish Transport Containers. The contribution is a mobile sensor platform for monitoring ponds. This system consists of the following architecture. It has the sensing node of each pond connected to a sink; this sink sends the information to a mobile application to have a visualization of the data in real time. This information is transmitted via GSM / 3G to the Internet, it can be monitored remotely and the information is stored in a database. In the results, the data of the ponds were shown remotely and the transport staff corroborated the measures. In conclusion, the monitoring platform showed excellent performance and precision in the test phase. In future works it is proposed to integrate artificial intelligence into the system to optimize and improve its functionality. This allows the system to be able to optimize resources using machine learning to analyze organisms and water conditions, in order to have an efficient control.

According to Wu et al, (2016) the use of smartphones or mobile devices in IoT applications such as agriculture can reduce energy consumption in terms of data generation, lessen manufacture and deployment cost, and is considered environmentally friendly as it reduces the number of deployed sensors.

Atat.R et al, (2017) developed a system facilitating Internet of Things in different applications connects different cyber physical systems (CPS) which are systems that comprises the interrelated physical objects and a computer program or application. This aid implementing their transfer of information. Today's technologies make receiving the data from CPS an easiest duty since low-cost smart sensors are available anywhere.

Most of prior works concerning fish farming systems and fisheries only considered to monitor water quality parameters limited to only few rudimentary standards. To further improve the study, it is also important to ponder on some of the other parameters that greatly affects the growth and quality of the fishes thus, the proponents considered using six different water quality parameters. In addition, the incorporation of automatic correction for the parameters suggests for a lesser work and stress not just for the owners but also for the fishes itself which some of the existing fish farming setups in various studies did not have.

Chiu et al., (2017) proposed the development of a system that would enable management of fishponds using a mobile device with the objective of reducing cost of fish farming and increase yield. The system composed of sensors for sensing the parameters, feeder mechanism for feeding the fish and CCTV cameras for capturing events around the fishpond. The feeding mechanism comprised of a motor, which is able to rotate to dispense the feed. The water level sensor was implemented using two water level sensors fixed at the bottom and the top of the fish tank. The system also utilized the SMS service to send commands to controllers and to display the pond status, which was one of the major short falls.

Raju & Varma, (2017) performed a work entitled as “Knowledge Based Real Time Monitoring System for Fish farming Using IoT” which uses several sensors such as Dissolved Oxygen, Temperature, Ammonia, Salt, pH, Nitrate and Carbonates but maintaining lots of sensors is costly and tedious. So, a system is needed which is not much costly and can determine the overall quality of the water effectively. This is the point, which is the base of our research.

Rauch et al, (1975) discussed different types of parameters and theoretical methods related to aquafarming. It consists of finding different structures and sizes and the amounts of quantities and their values. Here we can know types of water quality-related methods for finding the availability of food such that fish farming facility to raise lobsters. Some limits are established by using the information from control variables of commercial fish farming to the limits are finalized.

3.0 METHODOLOGY

This chapter explains methods and techniques used to collect data. In more detail, in this part the author outlines the research strategy, the research method, the research approach, the methods of data collection, the selection of the sample, the research process, the type of data analysis. This chapter contains all the sources of data use in this project.

Data Collection Tools

The researcher made use of both primary and secondary data. Primary data was useful by collecting data using prototype and face-to-face interviews to the farmers and manage of the station. Secondary data was used to understand IoT technologies deployed and selecting one that was appropriate to design an IoT system that would enable to capture data, analyse them, and display them to various end-users such as farmers.

Data Presentation

The purpose of the model was to enable the University of Rwanda Fish Farming and Research Station using the model to collect data using sensors and presenting data using Tables, line graphs in the purpose of monitoring culture tank, and prevent fish loss.

Research Quality

The research aimed at having a high level of precision by the use of the small coefficient of variation, which is 1 percent, which indicates the estimates could vary slightly due to the small sampling error margin provided. The researcher also aimed to improve the coefficient of variation by increasing the sample size. Construct validity will be used to ensure the study will focus on the relevant variables regarding the culture tank. The researcher interviewed the experts in the domain of agriculture to ensure the variables intended to be studied were valid. In addition, parallel forms reliability will be used by administering different versions of assessment tools, which were face-to-face interviews and questionnaires, to the same group of individuals

Study Measured Parameters

The water quality was assessed through measurement of physico-chemical parameters including The Temperature, pH, Total dissolved solids, Electrical Conductivity, Water level, Turbidity, DHT and Dissolved Oxygen (DO) using the developed prototype.

Figure 2: Measuring Water Quality in Culture Thank (Hatchery) Using Developed Prototype

The assessment of measuring water quality was done on the influent containing water from the culture thank (hatchery).

Application Development Methodology

The research adopted the Rapid application methodology, which was deemed best due to its iterative approach to applications development as it also delivers systems faster at a lower cost in time-constrained projects. This methodology was suitable for our research given the time constraints in developing the application.

Secondary data was used to determine the water quality aspects that require monitoring. Interviewing the operators of the culture tank also provided information on what should be incorporated in the model.

Components Used

Table 1: Hardware Requirement

Hardware	**Specification**	**Function**
Arduino UNO	Dual-inline-package ATmega328	Control the sensors
Water Temperature sensor	PVC jacket(±5oC)	Measure Temperature in water
pH sensor	Voltage: 5V, Current: 2mA	Measure PH in water
Electrical Conductivity sensor	Voltage: 3.0~5.0V, current: 3A	Measure Electrical Conductivity of water
Turbidity sensor	Voltage: 5VDC, Installation Resistance: 100m	Measure Turbidity level
Total dissolved solids sensor	Voltage: 5V, Working current: 3~6mA TDS measurement range: 0~1000ppm	Measure salinity level
Dissolved oxygen sensor	Voltage: 5V, Current: 2mA	Measure dissolved oxygen level
DHT sensor	Voltage: 5V, Current: 2mA	Measure environmental Temperature and Humidity
Ultrasonic sensor	Voltage: 5V Current: 2mA, Distance 2000 cm	Determine distance between two points.
PCB (Printed Circuit Board Prototype)	10cm x 22cm	Support the soldered electric component.
Solder wire	0.3mm core	Joining electrical component
Power Adapter	Voltage: 12 v	Powering circuit.
GPRS MODSULE	Size: 3.5x5cm Working voltage: 3.3-5v	Communication module
LCD screen	20x4 LCD	Display data sensed
Laptop	Computer with 8GB RAM,500GB free space of SSD CPU: Core i7	Programing provide console for microprocessor configuration.

Table 2: Software Requirement

Software	**Specification**	**Function**
Arduino IDE(Integrated Digital Environment)	Version 1.6 or Higher	Used to write and upload to microprocessor.
Python Anaconda	Version 35.3.0	Analyse data.
Client operating system	Windows 11	Provide platform for installing IDE

Machine Learning Algorithms

Machine learning is a branch of synthetic intelligence that allows computer structures to study directly from examples, information, and revel in. Basing on nature of the records generated with the aid of the IoT gadget, linear regression as machine studying algorithm is implemented (Dhanda,2022). Linear Regression is a device learning set of rules primarily based on

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supervised studying; it is one of the maximum commonplace fashions of machine studying that performs a regression challenge. It differs from other models because it estimates a numerical value. It accommodates a predictor variable and a based variable associated with each other in a linear style. This method is used while the variables are associated linearly. As its purpose in this research is the prediction of quantity to be distributed with the aid of the merchandising system, Decision Tree and linear regression may be used to fit a predictive version to a discovered facts set of values of the reaction and explanatory variables.

System Analysis and Design

This section discusses how the application was designed based on the data collected from the users. The discussion presents the interrelation between various modules of the application and their functions. The process of the analysis entails; understanding the current the situation, identify improvements, and finally defining the requirements of the proposed solution.

Conceptual Analysis

Data collected from the culture tank, were analysed to capture the farmers' and the various stakeholders' views on the current methods of fish farming water monitoring and suggestions of how the methods can be improved.

Importance of Water Quality Monitoring in recirculating fish farming system

Water quality is an important parameter for the health and growth of aquatic species in fish farming system. The threshold values of the water main parameters should be monitored continuously. Contaminated fish farming water will affect the health, growth and ability of animals to survive.

System Model

This system uses different technologies, including these Arduino modules, Sensors, database, Web Services, mobile application, and Desktop application. Figure 3 , shows the data flow and the three general blocks of the system: Sensors, Connectivity, and Deployment.

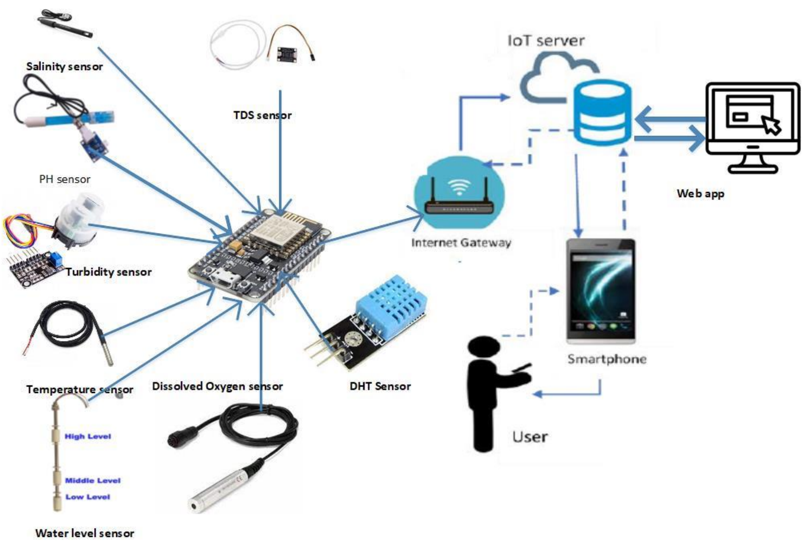

Figure 3: System Model

IMSA System Architecture

The system architecture is modular and gives an overview of how the various modules shall interact. As depicted in figure 3. The modules are described as follows:

Fish Farming Water

This is the fishpond where the fish is reared. It shall comprise various sensors that shall send data about water quality to a microcontroller.

Microcontroller

Upon receiving data, the microcontroller forwards it to the gateway. The communication between the gateway and the microcontroller is two-way.

Gateway

The gateway provides the link to the internet. It transmits the sensor data to the cloud server. Connectivity is one of the chief units of an Internet of Things (IoT) infrastructure, along with sensors/devices, data processing & user interface. For a device to step into the realm of the Internet of Things, it must be able to communicate with other devices. Different applications demand different sets of properties of connectivity, and fortunately, there is an overwhelming number of options (with the availability of multiple providers for each) and the count is still on the rise. The connecting technologies differ in their trade-offs among power consumption, range, bandwidth, security, and cost (Alam et al,2020).

In an ideal world, the ultimate one-size-fits-all connectivity solution would offer extremely low-power consumption for the devices while retaining the ability to quickly transmit huge chunks of data over long distances, with all of this provided at prices low enough for the smart businesses to remain economically viable. However, given the inherent heterogeneity of use cases within the Internet of Things, the sad truth is that no existing or near-future communication protocol will be able to accommodate all the possible smart applications while granting them no compromises in terms of the above-mentioned crucial IoT connectivity factors (Glória.A et al,2017).

IoT Cloud Server

The cloud server analyses the data received and acts per the predefined conditions. An IoT cloud is a massive network that supports IoT devices and applications. This includes the underlying infrastructure, servers, and storage, needed for real-time operations and processing. An IoT cloud also includes the services and standards necessary for connecting, managing, and securing different IoT devices and applications (Marques et al,2019).

IoT clouds offer an efficient, flexible, and scalable model for delivering the infrastructure and services needed to power IoT devices and applications for businesses with limited resources. IoT clouds offer on-demand, cost-efficient hyper-scale so organizations can leverage the significant potential of IoT without having to build the underlying infrastructure and services from scratch.

Choosing the right wireless technology is critical, thus, finding the best solution for a given project always involves negotiating a balance between three fundamental connectivity parameters: range, bandwidth, and power consumption. Consequently, the ability to recognize project requirements in every stage of its deployment and in-depth knowledge of the IoT use case specifics will greatly support the process of choosing the best-suited connectivity network for the smart enterprise (Glória.A et al,2017).

Application

The mobile application provides a means of visualizing the data on the server and provides an interface to the user for decision-making. End-user applications are an intrinsic part of an IoT infrastructure. These help users in monitoring and controlling IoT devices from remote locations. These applications transmit user commands to the cloud, and subsequently, to IoT-enabled devices connected to the network. Mobile apps, web apps, and desktop apps are the end-user applications found in an IoT infrastructure (Ogudo, K. A,2023). A website is essentially a group of web pages that can be accessed globally within a single domain. It is hosted on one or more servers. On the other hand, a web application is a program that can be accessed using a web browser. The front-end of web apps are usually created using HTML, HTML5 (responsive web app), JavaScript, and CSS. The backend code is in Java or .Net. It should be noted that there is no specific SDK for the development of web apps, unlike mobile apps (Kubler et al,2017).

Connecting the Internet of Things (IoT) and mobile apps make perfect sense. Smartphones offer IoT solutions to total portability. The user can manage IoT devices effortlessly via a mobile app, which makes everything more familiar. On the other hand, IoT will take mobile app development to a completely new level. Businesses around the world are closely watching and waiting to see what they can control with a smartphone. IoT app development is already showing the real potential to become a multi-million industry.

But it's not just about the money: the range of exciting devices and equipment that can be brought online increases every day (Patel,2018). Mobile apps play a significant role in considerably enhancing the growth of IoT as it allows for connection of devices that incorporate sensor. The relationship builds over the network and internet that produce detailed data and information. It does not require human-to-human or human-to-internet interaction. In this way, mobile apps are enhancing the growth of the Internet of Things. In this busy world, smartphones have streamlined our lives. And the best thing is that IoT has further smoothened our lives most favourably (Rajmohan & Srinivasan,2019).

Actuators

The actuators act upon the fish farming environment based on instructions received from the IoT cloud server.

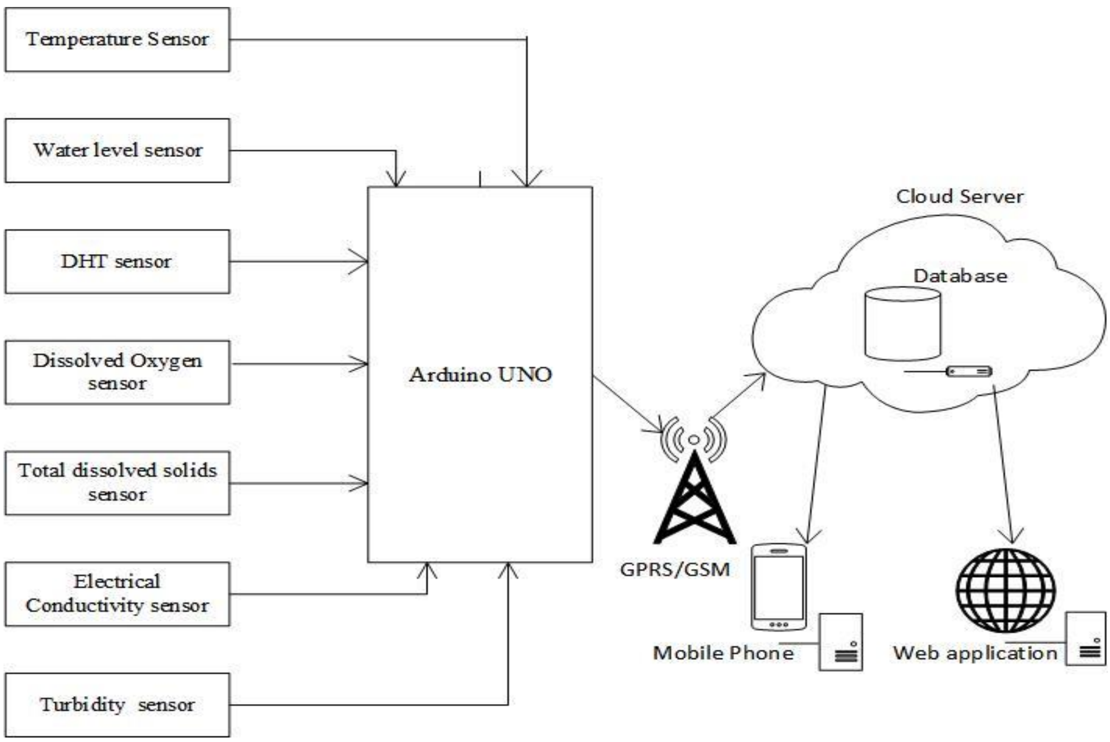

Figure 4: IMSA Architecture

System Algorithm

This work aims to design and implements a fish farming monitoring system as its saving time, lowering costs and electricity for the aqua farmer. As of now, aqua-farmers use manual check strategies for knowing the parameters of water. This will take longer and not be correct since water quality parameters could change concerning time. To avoid this downside, innovation should be involved in fish farming that improves the potency and limits the losses by constant checking of water quality parameters. The goal of this project is to design and execute a distributed system for fish farming water quality care through remote observing of turbidity, temperature, and pH. This work will contribute a remote monitoring framework through IoT to screen water quality in ponds. The system is portable, modular, low cost, and versatile and permits sharing of data through the cloud that can be used for the advancement and improvement of fish farming -related activities.

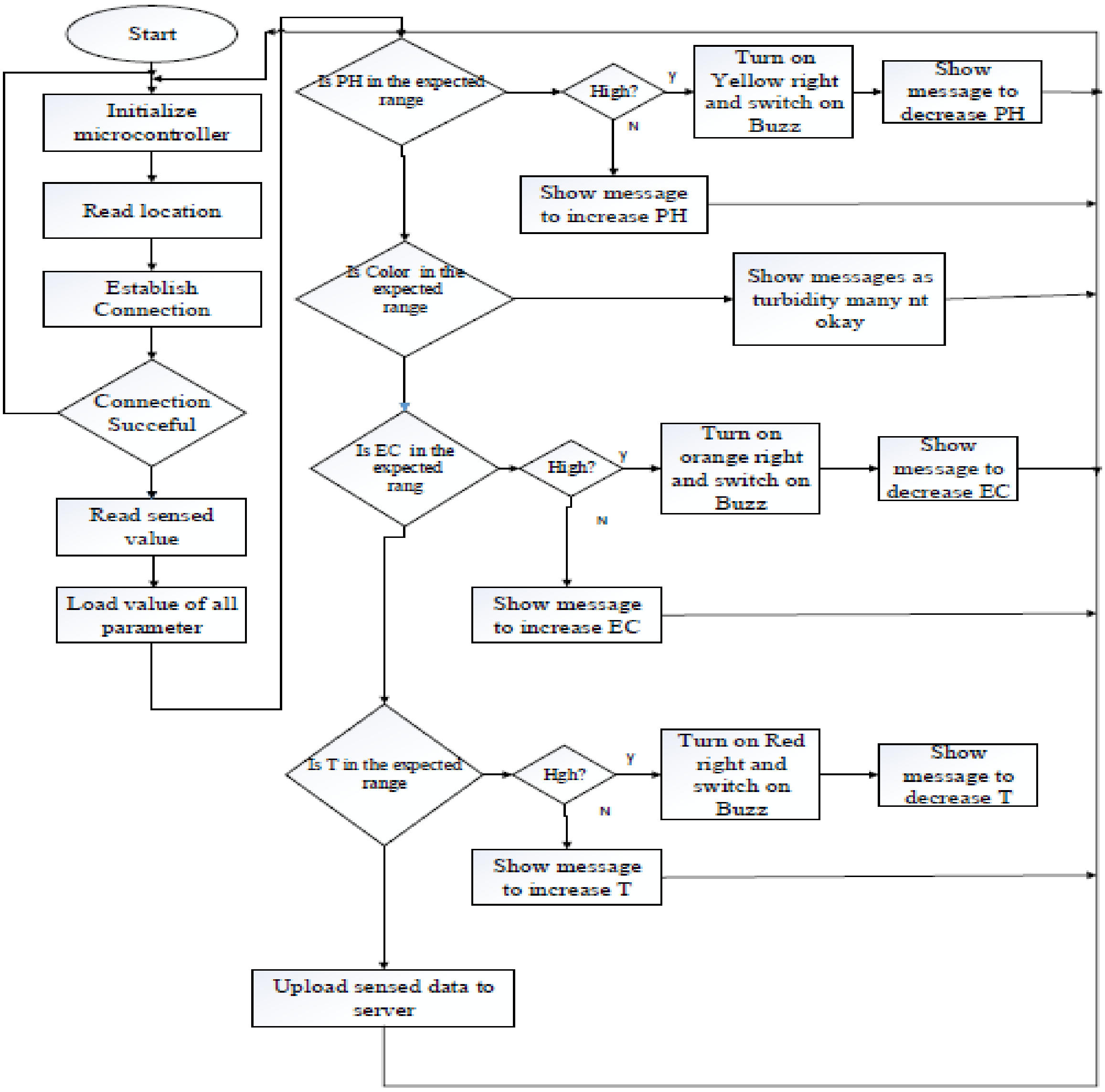

Figure 5: The Proposed System Algorithm

System Prototype

The hardware forms the core of the application. The various sensors were integrated into a printed circuit board. The sensors were connected to the processor via Arduino UNO using wire jumpers. Each sensor was connected and tested separately before they were integrated into one unit.

Figure 6: Experimental Setup

4.0 FINDINGS

This chapter discusses how the application was implement and tested. The various hardware and software platform that were used will also be disclosed. Sample codes and their implementation shall be displayed. The testing methodology and results shall also be discussed

System Analysis

The proposed system was successfully developed using the proposed hardware, software and architecture. The data is transmitted regularly, without errors and with a very small latency. The system was tested using the system in a local network A in which the computer is connected and is the place where the cabinet with the sensors is located. The 15 seconds counter is used to take the measurements every one minute. A request is sent to a sensor to take the measurement and when the request of each sensor is sent, the sensed information is sent to the application. In this same application, the information is store in a database and then is uploaded to web service. This service updates the server where it can then be requested by the mobile application. The results presented below are based on n = 9, sampling frequency of once per week and standard deviation

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Dashboard Design

The application dashboard is the graphical user interface that the users shall use to interact with application components. The application provides widgets that the administrator can add according to the use. Figure 7 shows sample forms for design dashboard. The dashboard contains menus and widgets that users can use to navigate the application

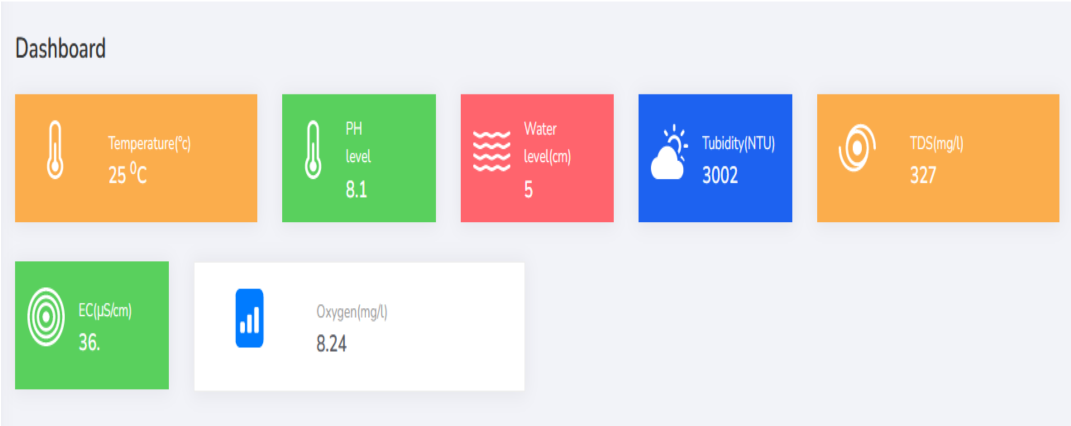

Figure 7: Dashboard Design sample display for real time of ph. level, Temperature level, water level, and Turbidity level in Pond

Coding Components

The main system functionality was to monitor the water quality parameters of the fish pond. The sensors installed would probe the various water quality aspects. To provide instruction code to the sensors, the system administrator has to write code on the IDE. Figure 8 shows the pseudo-code, which illustrates the general structure of the program execution. The hardware involved have to be initialized through respective libraries and a secure connection to the server in obtained by provide the authentication code. The main execution function operates in loop that will continuously probe the sensors in a predefined interval.

```
//Enter hardware library information
#include <SoftwareSerial.h>
SoftwareSerial DebugSerial(2, 3); // RX, TX

#include <BlynkSimpleStream.h>
// You should get Auth Token for bylnk app
char auth[] = "140a5da3f6e3490e99505e44d3a7c739";

void setup() {
  // Start serial communication for debugging purposes
  Serial.begin(9600);
  // Start up the library
  sensors.begin();

}

void loop() {
 call sensor fucntion ()
  display sensor values

}
```

Figure 8: Pseudo Code for Program Execution

Application Testing

The research utilized both unit testing and integration testing methodologies to ensure that the prototype functioned as per the user requirements. The results of test were presented in a scorecard in table layout as illustrated in Table 3

Table 3 : Application Test

S/No	**Function**	**Expected Result**	**Score**
Water Temperature sensor	Measure Temperature in water	Accurately measure the Temperature of water in the pond	Pass
PH sensor	Measure PH in water	Accurately measure the pH of water in the pond	Pass
Electrical Conductivity sensor	Measure Electrical Conductivity of water	Accurately measure the EC of water in the pond	Pass
Turbidity sensor	Measure Turbidity level	Accurately measure the Turbidity of water in the pond	Pass
Total dissolved solids sensor	Measure salinity level	Accurately measure the TDS of water in the pond	Pass
Dissolved oxygen sensor	Measure oxygen level	Accurately measure the DO of water in the pond	Pass
DHT sensor	Measure Environment Temperature and Humidity	Accurately measure the temperature of room	Pass
Water level sensor	Measure water level	Accurately measure the level of water in the pond	Pass
Sensor chat		Sensor Historical data	Pass

4.0 DISCUSSIONS AND RESULTS

Discussions

In this section, we shall discuss the findings of the implementation of the IoT monitoring in fish farming system model, culture tank water quality monitoring model and the limitations of the model. The model was designed and developed based on the review of literature in chapter 2. The model focused on two water quality aspects namely: the water temperature and Dissolved oxygen. The literature review detailed the importance of these quality aspects. Fish species require varied optimal water conditions for them to survive in the water and thus University of Rwanda Fish Farming and Research Station have to be set for the different water bodies the fish live in. It was revealed that the changes in either of the quality affects fish welfare hence the need for constant monitoring.

The purpose of the model was to enable the University of Rwanda Fish Farming and Research Station using the model take proactive action when the thresholds for the various parameters are achieved in order avoid losses such as fish kills and feed wastage. A second questionnaire was administered to a subsection of the population of respondents that were that were involved in the model requirements stage. The respondents were given an opportunity to use the model and later gave their opinion on the various aspects of the model design. The subsequent sections shall discuss the aspects of the model that were tested and the respondents' feedback. Line charts was the researcher's instrument of data presentation and for the analysis, we have use machine learning by using python as tool for analysing data.

Dataset (List of Observation)

After deploying the senses in the pond, the sensor starts to collect data and send it to the cloud server and the data will be analysed by anaconda software. This Table 4 shows the data collected in recirculating system on different time.

Table 4 : Dataset from Recirculating System

No	PH	Temp°c	Water Level (Cm)	Tubidity (Cm)	TDS (Mg/l)	EC (Ms/Cm)	Atmc Temp	Oxygene (Mg/l)	Time
1	8.1	25°c	5	3002	327	36	26	8.24	1/13/2022 14:42
2	8.1	25°c	9	3002	320	35	26	8.24	1/13/2022 14:42
3	8	25°c	8	3004	311	34	26	8.24	1/13/2022 14:41
4	8.1	25°c	102	3005	320	35	26	8.24	1/13/2022 14:41
5	8.1	29°c	5	3004	364	40	30	7.54	1/13/2022 14:22
6	8.2	29°c	5	3004	375	42	30	7.54	1/13/2022 14:22
7	8.2	29°c	5	3004	361	40	30	7.54	1/13/2022 14:22
8	8.1	29°c	5	3005	379	42	30	7.54	1/13/2022 14:21
9	8.1	29°c	5	3005	383	42	30	7.54	1/13/2022 14:21
10	8.1	29°c	5	3005	361	40	30	7.54	1/13/2022 14:20
11	8.1	29°c	5	3005	373	41	30	7.54	1/13/2022 14:20
12	7.9	24°c	2296	2608	787	88	25	8.4	1/10/2022 18:08
13	8	24°c	2297	3001	531	59	25	8.4	1/10/2022 18:08
14	8	24°c	2297	2958	531	59	25	8.4	1/10/2022 18:07
15	8	23°c	2196	2046	264	4	23	8.56	12/17/2021 15:55
16	8	23°c	2196	2801	255	4	23	8.56	12/17/2021 15:55
17	8	23°c	225	2046	250	4	23	8.56	12/17/2021 15:54
18	8	23°c	224	1952	255	4	23	8.56	12/17/2021 15:54
19	8	23°c	2196	2904	289	4	23	8.56	12/17/2021 15:54
20	8	23°c	103	2901	298	4	23	8.56	12/17/2021 15:53

Results

After collecting data in the culture tank, I have to try to sort it and look which parameters that have an impact on the loss of fish and we took two parameters temperature and oxygen we try filter the data according to the date and day (Table 4). The plot content for parameters varies depending on loss vs Oxygen and temperature the priority of those parameters is also different, where the dissolved oxygen (DO) is the highest priority for fish farming that determines the growth of the fish. Increasing water temperatures can also cause the DO content to decrease, as it is unable to hold O2. However, if dissolved oxygen (DO) is too high it will cause a gas bubble disease that can kill fish. If too low, cause fish are easily infected with bacteria. The Ambient temperature also affects the daily fluctuations of dissolved oxygen. Figure 6 shows different sampling of fish pond and recirculating system (production process).

It should be clear now that a recirculating fish farming is a complex dynamic system with many variables that need to be understood to manage successfully. A common setup of treatment functions in Recirculating fish farming systems consists of solid waste removal, oxygen addition; strip the system of CO 2 and a nitrification process to transform ammonia to less harmful nitrite. The Recirculating fish farming systems reuses up to 90-95% of the water, so there has to be some water source to provide all the water.

Water outflow will carry accumulated waste and any other chemicals dissolved in the water out of the system. On the other hand, water inflow can be rich of oxygen, and other chemicals, dependent on the water source. Recirculating fish farming systems are an expensive facility so the fish has to be stocked as densely as possible for the system to be economically profitable. The total biomass that can be stocked is determined by the oxygen consumption of the fish. Water quality is what defines recirculating fish farming. The water has to be at the highest quality possible so that fish can be grown at such a high density and water quality in the rearing tank depends on two things: The quality of the influent water and changes in the water inside the rearing tank, which is driven by feed input and biological activity.

Model Results Comparison

Modulation was successfully we have to try to modulate the data collected in the fishpond by using Linear Regression, KN Regressor, and Decision Tree all those tests have passed successfully where linear regression has high accuracy than other models and we recommend using this model because it has the best accuracy.

Table 5: Model Results Comparison

Metrics	Dataset	KNRegressor	Linear Regression	Decision Tree
SCORE	Training	75%	84%	88%
	Testing	84%	92%	88%
MSE	Training	14	9	6
	Testing	8	4	6

CONCLUSION AND RECOMMENDATIONS

Conclusion

The method assisted in identifying possible improvements in the fish farming sector by thoroughly analysing all of the products, services, and segments involved in this sector. The higher costs and key challenges of each of them were identified, which served as a good starting point for looking at how technologies could solve the challenges and/or reduce costs. The experiments were conducted and to control the pH, DO concentration, and temperature of water, ultrasonic sensors were installed in the culture tanks. A microcontroller were designed, it was confirmed that the optimal water temperature range was from 23 to 30 °C, the optimal DO concentrations were from 6 to 15[mg/L], and the optimal pHs were from 5 to 9. The automatic control and real-time monitoring are performed using the sensors, and the measured big data are stored in a server.

Although the system may be accessible via the Internet (cloud), fish growers and others in charge of monitoring the fish in the tank rarely check the water for changing conditions. This has resulted in losses and has made fish farming a costly endeavour because farmers invest in high-cost supplies such as feeds that do not provide returns. As a result, real-time monitoring and early intervention in response to these environmental changes are critical to finding a solution to this problem. By suggesting and testing an alternate model, the researcher was able to satisfactorily overcome the models' shortcomings. The model's development was made possible by the convergence of two developing technologies: a web application and wireless sensor technologies. Farmers will be able to track changes in water quality and make timely judgments, allowing them to take corrective action immediately.

Recommendations

Following a review of the literature and interviews with experts and based to project results, it was discovered that there are various more elements to consider while caring for fish welfare. In the future, using the measured big data from the sensors, we can extend this research to an automatic farm program by deriving the optimal growth conditions of eels through an artificial intelligence program, which is expected to contribute greatly to the domestic and overseas smart farming industry. This prototype is still in development; however, in the future, redundant devices can be incorporated if one of the sensors fails.

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