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IoT Based realtime fish pond water quality monitoring model

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IoT Based Realtime Fish Pond Water Quality Monitoring Model

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Declaration

I declare that this work and has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

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Abstract

Fish farming contributes significantly to food security in developing countries throughout the world. It supplements income and is a source of protein in majority of rural and urban homes. Fish farmers however, are faced with numerous challenges during the production period and key among them is the monitoring and management of the production resources. Water is the main resource in the fish farming process. The lack of effective monitoring of water quality and timely intervention in instances where there are changes in the quality aspects such as temperature and water levels, has led to resource wastages and losses to the farmer due to low production. However, in Kenya most fish farmers are yet to adopt technology in their production processes. Most farmers rely on their experience when it comes to making decisions in control actions; which most of the time are susceptible to errors due to the complexities involved. The advent of the Internet of Things (IoT) is opening various ways in which farmers can rare fish by simply installing inexpensive sensors which are able to communicate with smartphones and provide a means of monitoring and managing the fish ponds.

This research proposes a solution which is a real time fish pond water quality monitoring model which utilizes a smartphone that shall be adopted by the farmers. The model utilizes 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 via a microprocessor to a graphical user interface (GUI) on the farmer's smartphone. The farmer can then act as per the information relayed or the model can automatically act on behalf of the farmer as per the predefined actions. The data gathered by the model can be extracted in various forms for analysis. The real time information shall enable timely intervention by the farmers which eventually helps minimizing or eliminate wastages. A rapid prototyping methodology was used where the requirements of the system were gathered and the components designed and tested throughout the process.

Table of Contents

Declaration ... ii

Abstract ... iii

List of Figures ... viii

List of Tables ... x

Abbreviations and Acronyms ... xi

Definition of terms ... xii

Acknowledgements ... xiii

Dedication ... xiv

Chapter One: Introduction ... 1

1.1 Background of Study ... 1

1.2 Problem Statement ... 2

1.3 Research Objectives ... 3

1.4 Research Questions ... 3

1.5 Justification ... 3

1.6 Scope and limitations ... 3

Chapter Two: Literature Review ... 4

2.1 Introduction ... 4

2.2 Aquaculture production in Kenya ... 4

2.3 Fish Kill Problem ... 6

2.4 Physical aspects of Water Quality in fish pond culture ... 7

2.4.1 Water Temperature ... 7

2.4.2 Water Turbidity ... 8

2.4.3 Water Level ... 8

2.5 Chemical Aspects of Water Quality in fish Pond Culture ... 8

2.5.1 Dissolved Oxygen (DO) ... 8

2.5.2 Water pH ... 9

2.5 The Internet of Things (IoT) Concept ... 10

2.5.1 Sensor-Based IoT System Architecture ... 11

2.6 Applications used in fish pond water quality monitoring ... 13

2.6.1 IoT Enabled Real-Time Fishpond Management System 13
2.6.2 Water monitoring IoT system for fish farming ponds with Wivity^{TM} module 14
2.6.3 GSM based fish monitoring system using IoT... 15
2.7 Conceptual Model 16
Chapter Three: Research Design and Methodology.. 18
3.1 Introduction.. 18
3.2 Research Design 18
3.3 Application Development Methodology 19
3.3.1 Data collection instruments... 20
3.4 Data Analysis Presentation 20
3.6 Target Population and Sampling... 20
3.7 Ethical Consideration.. 21
3.8 Experimental setup 21
Chapter Four: System Analysis and Design.. 22
4.1 Introduction.. 22
4.2 Data Analysis and Results 22
4.2.1 Years of fish farming experience 22
4.2.2 Importance of fish pond water quality monitoring.. 22
4.2.3 Frequency of water quality check 23
4.2.4 Technology usage... 24
4.2.5 Timeliness of the current process of water monitoring.. 24
4.2.6 Recommendation of a water quality monitoring application 25
4.3 Application User Requirements.. 25
4.3.1 Application Functional Requirements.. 25
4.3.2 Application Non-Function Requirements 26
4.4 Application Architecture.. 26
4.5 Process Modelling.. 27
4.5.1 Context Level Diagram 27
4.5.2 Level 1 diagram.. 28
4.5.3 Use case modelling.. 29
4.5.4 Use Case Descriptions.. 29

4.5.5 Sequence diagram ... 31
4.5.6 Activity Diagram ... 32
Chapter Five: Implementation and Testing ... 34
5.1 Introduction ... 34
5.2 Application Hardware and software Requirements ... 34
5.3 Hardware Assembly ... 35
5.3.1 Circuit design ... 35
5.4 Software Configuration ... 35
5.4.2 Initial configuration ... 36
5.4.2 Dashboard Design ... 36
5.4.3 Coding Components ... 37
5.5 Algorithm Implementation and Validation ... 38
5.6 Application Testing ... 40
Chapter Six: Discussions ... 42
6.1 Introduction ... 42
6.2 Graphical User Interface ... 42
6.3 Reliability of the model ... 43
6.4 Performance ... 44
6.5 Relevance of the model ... 44
6.6 Application Limitations ... 45
Chapter Seven: Conclusion and Recommendations ... 46
7.1 Conclusion ... 46
7.2 Recommendations for further research ... 47
References ... 48
Appendices ... 52
Appendix A: User Requirements Questionnaire ... 52
Appendix B: Application Functionality and Usability Questionnaire ... 53
Appendix C Krejcie & Morgan Table ... 54
Appendix D Ultra Sonic Sensor Specifications ... 55
Appendix E Waterproof Temperature Sensor Sepcifications ... 56
Appendix F Originality Report ... 57

List of Figures

Figure2.0: Pond Culture……………………………………………………………………...….4

Figure 2.1: Difficulties in managing ponds by fish farmers in Siaya County…………………5

Figure 2.2: Problems faced in the management of ponds…………………………………...5

Figure 2.3: pH ranges showing tolerance limits and optimum range for fish……………….....9

Figure 2.10: Daily fluctuations of PH in fish pond water ……………………………....…...10

Figure 2.11: Architecture of IoT (A: three layers) (B: five layers) ……………………………11

Figure 2.12: A Sensor-Based IoT System Architecture………………………………………12

Figure 2.13: IoT Enabled Fish Pond Management System ………………………………...14

Figure 2.14 Water monitoring IoT system for fish farming ponds with Wivity module……….15

Figure 2.15: Framework for GSM Based Fish Monitoring System Using IOT………………16

Figure 2.17: Conceptual Model for Water Quality Monitoring…………………………..........17

Figure 3.1: Applied Research Approach ……………………………………………………...18

Figure 4.1: Farmers experience in fish farming……………………….………………………22

Figure 4.2: Importance of water quality monitoring………………………………………..23

Figure 4.3: Frequency of water checks……………………………………………………...23

Figure 4.4: Technology Usage………………………………………………………..........24

Figure 4.5: Timeliness of current process…………………………………………………….24

Figure4.6: Recommendation of a smartphone-based water quality monitoring application…25

Figure 4.7: Fish Aquaculture Monitoring System Architecture ……………………………….27

Figure 4.8: Context Level 0 Diagram…………………………………………………………28

Figure 4.9: level 1 diagram…………………………………………………………………….28

Figure 4.10: Use Case Diagram for IoT-based Real Time Fish Pond Water Quality monitoring……………………………………………………………………………………29

Figure 4.11: Fish pond water quality monitoring process Sequence diagram……………….32

Figure 4.12: class diagram for water monitoring application…………………………………33

Figure 5.4: Temperature Sensor wiring…………………………………………………………….35

Figure 5.5: Ultrasonic Sensor wiring…………………………………………………………….35

Figure 5.6: Application program flow……………………………………………...……….36

Figure 5.7: Notification for water level and temperature thresholds…………….……………37

Figure 5.8 sample dashboard………………………………………………………..……….38

Figure 5.9: Pseudo code for program execution…………………………………………………38

Figure 5.10 sample code for water level measurement……………………………………….39

Figure 5.11: Incorrect password input…………………………………………………………40

Figure 5.12: Water level history data display……………………………………………………41

Figure 5.13: water level and temperature status………………………………………………41

Figure 6.0: Application Usability……………………………………………………………….43

Figure 6.1: Application Reliability………………………………………………………………43

Figure 6.2: Application's performance………………………………………………………… 44

Figure 6.3: Relevance of the application……………………………………………………....45

List of Tables

Table 1: Major threats, indicators of threats and impact……………………………………7

Table 2: DO requirements commonly farmed fishes in Kenya ……………………………….9

Table 4.1: Add User Use Case……………………………………………………………..28

Table 4.2: Detect Water Level Use Case…………………………………………………...28

Table 4.3: Detect turbidity Use Case………………………………………………………29

Table 4.4: Replenish Water Use Case……………………………………………………..29

Table 4.5: Dispense Feed Use Case………………………………………………………..30

Table 5.2: Hardware requirements…………………………………………………………33

Table 5.3: Software requirements…………………………………………………………33

Table 5.1: Application Test………………………………………………………………39

Abbreviations and Acronyms

API	-	Application Programming Interface
DO	-	Dissolved Oxygen
ESP	-	Economic Stimulus Program
FAO	-	Food Agricultural Organization
GDP	-	Gross Domestic Product
GOK	-	Government of Kenya
GSM	-	Global System for Mobile Communication
GUI	-	Graphical User Interface
ICT	-	Information communication Technology
IDE	-	Integrated digital Environment
IoT	-	Internet of Things
LoRaWAN	-	Long Range Wide Area Network
NGO	-	Non government Organization
PH	-	Hydrogen Power
REST	-	Representational State Transfer
WSN	-	Wireless Sensor Networks

Definition of terms

Actuator : A mechanism that acts upon the environment

Aquaculture :Aquaculture is the farming of aquatic organisms including fish molluscs, crustaceans and aquatic plants (FAO, 2016a) .

Fish pond culture : is growing of fish in ponds

IoT Cloud : It is a platform that connects devices to cloud services

Microcontroller : Is an integrated circuit designed to perform specific function in an embedded system

Sensor : A device that detects and responds to some form of input in the environment

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Dedication

I dedicate this research project to my parents, wife, children and colleagues. I wish sincerely thank them for their support, constant encouragement and the believe they had in me that enabled me complete this proje

Chapter One: Introduction

1.1 Background of Study

Fish accounts for 17 per cent of the global animal protein intake and 6.7 of all protein consumed (FAO, 2016). Fish farming has played a significant role in providing more fish and helped in keeping the fish prices down. This situation has increased the number of stakeholders involved in food security to not only farmers and agricultural specialists but also researchers who strive to develop new techniques that will increase food production with an efficient return-on investment methodology (Sravanth Goud & Sudharson, 2015).

Fish provides healthy animal protein which has led to an increase in the number of fish famers in Kenya, especially in areas where fish was not produced before. Aquaculture has thus become a source of livelihood to many in Kenya (FAO, 2005). Just like numerous nations in Africa, fish farming in Kenya is characterized by low levels of pond production that have stagnated over the past decade. The practice was initially introduced by the colonialists as a sport in 1900s and it evolved to static water pond culture of tilapia fish in the 1920s, later supplemented by common carp and catfish. In order to produce seed for the warm water and cold water species for stocking of rivers, dams and ponds; the colonialists set up two fish farms in 1948, the Sagana Fish Farm and the Kiganjo Trout Farm (FAO, 2005). Aquaculture provides the most practical solution in an era where the natural supply of wilds stock is diminishing (Mbugua, 2008), .

The quality of water in the fish ponds is a major contributing success factor in pond aquaculture. The welfare of the fish highly depends on the quality of water its reared in (Towers, 2015). Different spices of fish require varying ranges of the various water parameters for them to thrive. Variations in the water quality aspects can adversely affect the fish and in many instances lead to fish kills. The pond water quality might change rapidly hence the need for constant monitoring and emergency interventions incase the changes occur (Helfrich & Smith, 2009).

The ICT sector in Kenya has been expanding with a growth of 10% to 22% in 2017 which contributed to 1.6% of total GDP (Wasonga, 2018). According to (Jumia, 2019), this growth is attributed to factors such as; mobile absorption with 91% (46.94M) penetration of mobile subscriptions and internet connectivity at a penetration rate of 84% with 43.3M of the total population having access to the Internet in Kenya (Kemp, 2019). Smartphones have become part and parcel of our daily lives owing to factors such as: affordability, portability and ubiquitous (Huan, Liu, Li, Wang, & Zhu, 2014).

The Ubiquitous nature of internet connectivity has aided in providing opportunities for innovations and services which lower operational costs at the same time provide additional revenue streams for organizations (Cognizant, 2014). The current trend of technologies is converging on mobile technologies. The IoTs is among the emerging technologies that is quickly gaining cognizance and acceptance in many fields due to its practicability in improving everyday chores (Bamigboye & Ademola, 2016). According to Cognizant (2014), this emergence is driven by a combination of factors such as: the exponential growth of smart devices and the convergence of low-cost technologies for example, the Wireless Sensor Networks (WSN).IoTs in agriculture can optimize the production process and can scale from small to big farmers (Gnanaraj & Jayanthi, 2015).

According to (Rizzo, 2015), there are three important variables that need to be optimized in agriculture for farm management to be profitable these are (a) production yield, (b) production cost, (c) and risk avoidance. Further, there's need to have a real time, holistic picture of these variable to maximize profit.

1.2 Problem Statement

Many fish farmers rely on traditional water quality monitoring methods such as notes writing and observation which are prone to errors (Helfrich & Smith, 2009). Most farmers are yet to embrace technology in the monitoring of water quality in the fish ponds. According to (Idachaba, Olowoleni, Ibhaze, & Oni, 2017) fish pond operators are faced with the challenge of constantly monitoring water quality and changing the water in case the quality is compromised.

The proposed model in this work shall aid fish farmers in monitoring fish ponds using IoTs. The integration of sensor and internet technology combined with a user-friendly interaction interface via a smartphone to provide real time monitoring of the fish ponds; could make a significant contribution in reducing the risk of losses and improve efficiency (Neethirajan, 2016).

1.3 Research Objectives

i. To investigate the water quality parameters useful for monitoring fish ponds.
ii. To review the models used in monitoring water quality in fish ponds.
iii. To develop a model for real time monitoring of water quality in fish ponds.
iv. To test the functionality model.

1.4 Research Questions

i. What are the parameters for monitoring water quality in fish pond?
ii. What are the challenges in the existing models?
iii. How can the model for monitoring the water quality be developed?
iv. How can the functionality of the model be tested?

1.5 Justification

This research contributed in developing a technological solution for real time monitoring water quality aspects of fish ponds that shall be adopted by fish farmers in Kenya by providing them with real time data whenever they are within or away from the fish pond site. This will help them eliminate or minimize the risk of losing fish and wastages due late interventions.

1.6 Scope and limitations

The research focused on developing a model for real time monitoring of fish ponds as a proof of concept and testing the basic functionalities of the model. The functionalities tested were monitoring of temperature and water level aspects of the water. The hardware platform used provides extra ports which can be used scaled up the model to incorporate more sensors.

Chapter Two: Literature Review

2.1 Introduction

This chapter presents a discussion on the challenges faced by farmers in monitoring the water quality, the key parameters used in aquaculture water monitoring. The various application architectures used for the monitoring were reviewed and used as a basis for developing the model which was an improvement of the already existing models.

2.2 Aquaculture production in Kenya

The Economic stimulus program (ESP) contributed significantly to the growth of aquaculture in Kenya. It accelerated regional development and commercialization of farming activities (Meijberg, 2016). Aquaculture contributes 1% of the total nation fish production. Approximately 1000 metric tons are harvested from 7477 small ponds owned by about 4742 fish farmers. The current mean yield from fish farming is approximately 5.84Mt/ha/year. However, by 2013, fish accounted for 17 percent of the global population's intake of animal protein and 6.7 percent of all protein consumed (FAO, 2016b). The pond culture is the most practiced form of aquaculture in Kenya. Figure 2.1 shows a typical pond culture

Figure 2.0: Pond Culture (Meijberg, 2016)

According to (Shitote, Wakhungu, & China, 2013), there are a host of problems facing the growth of Kenya's fish farming industry. These challenges include; uncoordinated promotion of fish farming through many institutions, Government, research institution, Universities, NGOs and Regional authorities among others. In their study, (Shitote et al., 2013) noted that the slow pace of fish farming in Siaya county in western Kenya was attributed to: high cost of feed, shortage of quality fingerlings and feeds, flooding, poor security and poor management practices among others. Mbugua (2008), noted that poor record keeping and insufficient statistical data impeded information on the viability of aquaculture. In their study, Shitote et al. (2013) also noted that majority of the farmers faced various difficulties in managing their ponds while very few faced no problems as depicted in figure 2.1

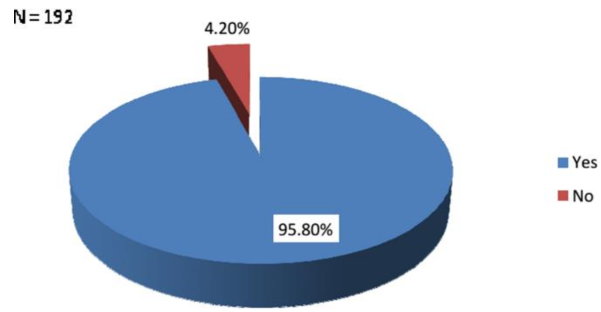


Figure 2.1: Difficulties in managing ponds by fish farmers in Siaya County (Shitote et al., 2013)

Further, the farmers were asked what difficulties they faced and they gave varied responses with varied degrees of severity as recorded in figure 2.2. It is noteworthy that some of the variables that constitute the degree of severity such as: pond maintenance and siltation of ponds; are features that require constant monitoring.

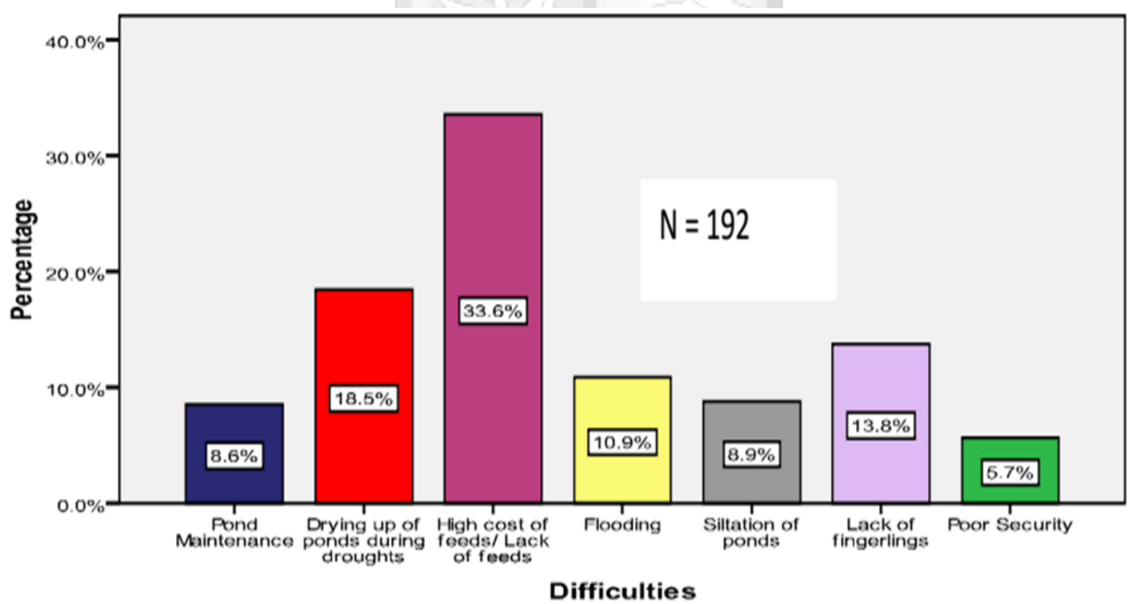


Figure 2.2: Problems faced in the management of ponds (Shitote et al., 2013)

2.3 Fish Kill Problem

Fish kill is an event where there's a sudden appearance of dead fish in the fish ponds. 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 (Sallenave, 2013)

According to (Helfrich & Smith, 2009) most fish kills are as a result 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 water weeds 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 (Idachaba et al., 2017). 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., 2013). 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 aquaculture as identified by (Virapat, Wilkinson, & Soto, 2017a) is summarized in table 1. 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.) (GOK, 2016)

Table 1: Major threats, indicators of threats and impact (Virapat, Wilkinson, & Soto, 2017b)

Threats	Physical/chemical	Biological	Socio-economic	Threat indicators	Impact indicators
Floods and droughts	Large change in water quality (increased turbidity, nutrient load, temperature, salinity, pollution, supply problems)	Reproductive Disease risk Mortality Growth rate Algal blooms and eutrophication Temperature stress	Infrastructure, property damage Crop loss/escapees Shortened culture period Job/livelihood loss Food security Conflict over water management Logistical interruptions (feed and seed supplies) Pumping costs	Rainfall River flow and level Reservoir storage capacity/level Inundation area Turbidity Algal density Nutrients Salinity	Infrastructure damage Water quality Turbidity Disease Mortality Algal blooms Loss of infrastructure Crop loss Job/livelihood loss Food insecurity Number of conflicts Logistical interruptions (road blocked, etc.) Production costs Food conversion ratio (FCR) Escapees Loss of life Impact on women, children, elderly and infirm (e.g. livelihoods, nutrition and more)
Extreme temperature fluctuations	O_2 levels Salinity Stratification	Harmful algal blooms Temperature stress Mortality Disease Natural food availability Cage fouling	Broodstock/crop loss Shortened culture period Job/livelihood loss Food insecurity Higher insurance costs	Temperature (air, water) Nutrients (conductivity, etc.)	Water quality Disease Mortality Algal blooms Crop loss Production cost (e.g. aeration, pumping cost) FCR
Unusual water level fluctuations (e.g. river, reservoir levels and flow)	Bank erosion Sedimentation Water quality (turbidity, temp, etc.)	Stress Disease Escapees		Water level Flow	Water quality Turbidity Salinity Disease Mortality Algal blooms Crop loss Job/livelihood loss Food insecurity Number of conflicts Production cost FCR
Saline intrusion into coastal estuaries (sea level rise, reduced flow levels)	Chemical and/ or water-quality parameters	Mortality Stress Disease Algal blooms	Loss of farming area/ sites Conflict with other users of water Low production	Salinity	Water quality Turbidity Disease Mortality Algal blooms Crop loss Job/livelihood loss Food insecurity Number of conflicts Production cost FCR
Extreme climatic events (storms, wind, wave amplitude)	Large change in water quality (increased turbidity, nutrient load, lower temperature) Pollution	Disease risk Mortality Algal blooms Escapees	Infrastructure/ property damage Crop loss Job/livelihood loss Loss of life Food security Logistical interruptions (feed and seed supplies)	Forecasts Water level (reservoirs, rivers)	Water quality Turbidity Disease Mortality Algal blooms Crop loss Job/livelihood loss Food insecurity Infrastructure loss/damage Loss of life Impact on women, children, elderly and infirm (e.g. livelihoods, nutrition and more)

2.4 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 (GOK, 2016).

2.4.1 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

(GOK, 2016). (Ngugi, Bowman, & Omolo, 2007), prescribed two ways in which temperature can be controlled: (a) Stock fish whose body temperature range much water available in your location and (b) add cooler water to lower temperature

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

2.4.2 Water Turbidity

Water that is turbid is referred to as "cloudy". Low water visibility commonly results from suspended solids like clay or plankton (living organisms in water) (GOK, 2016). Clay can reduce the water visibility to 30cm or less hence impede the growth of plankton. These two causes can be remedied as follows (Ngugi et al., 2007) (a) Use diversion canal to divert muddy water**,** (b)treat the water with lime at recommended pH for improving soil PH and alkalinity**,** (c) frequent observation of the pond during culture period and take appropriate action (d) Remove plankton if visibility is low (e) add plankton if visibility is high.

2.4.3 Water Level

The variation in fish pond water levels affect the behavior of the fish. Fish have a tendency of moving to specific areas of the pond where they can feed and relax. When the water level for the area shrinks, then is likely to cause competition for survival among the fish (S & A., 2018) .

2.5 Chemical Aspects of Water Quality in fish Pond Culture

Chemical aspects refer to the following parameters: pH, alkalinity, hardness, dissolved gases (Oxygen, Ammonia, Nitrogen, Carbon dioxide). Water reacts differently depending on the dissolved substances in it and thus affect the living organism in it (GOK, 2016).

2.5.1 Dissolved Oxygen (DO)

Oxygen is the most important gas dissolved in water. It mainly dissolves through the atmosphere and photosynthesis. Photosynthesis is the major source though it depends on the amount of light available to the aquatic plants (GOK, 2016). Table 2 shows the DO requirements for various fish species stocked in Kenya. Low oxygen levels can lead to sudden fish kills.

Table 2: DO requirements commonly farmed fishes in Kenya (in mg/l or percent saturation values) (GOK, 2016)

Adults			
Fish species	**Ova and juveniles**	**Minimum DO level**	**Preferred DO level at least equal to**
Trout	Close to 100%	5 mg/l (50%)	8 mg/l or 70%
Common carp	At least 70%	3 mg/l (30%)	5 mg/l or 50%
Tilapia	At least 70%	2 mg/l	4 mg/l or 50%
African catfish	At least 90%	1 mg/l or less (aerial respiration)	3 mg/l or 35%

There various ways to manage dissolved oxygen levels as prescribed by (Ngugi et al., 2007): (a) Feed fish at the recommended daily rates to avoid overfeeding which will result to feed wastage and compromise oxygen levels (b) reduce feeding rate during cloudy weather, slow growth periods and when the temperatures are unusually high (c) running bubbling fresh water into the pond in emergency situations and simultaneously release oxygen poor water near the bottom of the pond.

2.5.2 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.

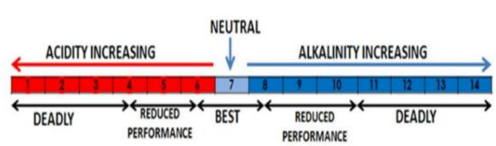


Figure 2.3: pH ranges showing tolerance limits and optimum range for fish, (GOK, 2016)

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 (Boyd & Pillai, 1985). Figure 2.10 illustrates the fluctuation in PH of fish pond culture

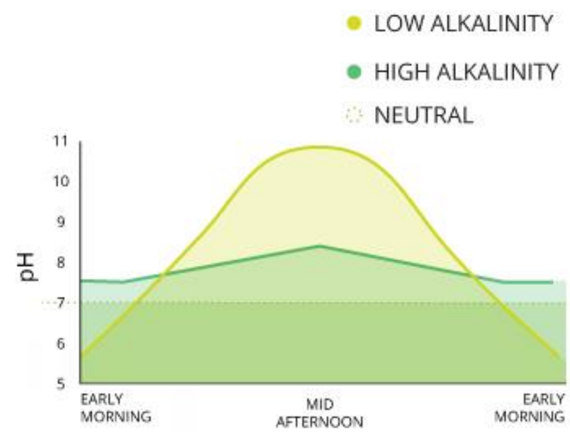


Figure 2.10: Daily fluctuations of PH in fish pond water (Fondriest Environmental, Inc., 2013)

2.5 The Internet of Things (IoT) Concept

Recent developments in the communication technology and mobile sector has enhanced the development and use of ICT in farming (Banhazi et al., 2012). IoT is one of the recent ICT technologies that has been pivotal in the realization of IoT in farming. It provides the ICT infrastructure that enables 'thing's to exchange information over the internet securely and reliably (Weber & Weber, 2010). It is a complex platform based on connection of things for example, tagged objects, sensors, actuating elements and various technologies (Weber & Weber, 2010).

Various authors have defined IoT in different ways. In their book, (Vermesan, Friess, & P., 2011) defined IoT as simply an " interaction between the physical and digital worlds. The digital world interacts with the physical world using a plethora of sensors and actuators." Generally internet of things is described as interconnection of devices that are interconnected to achieve tasks that require intelligence (Sethi & Sarangi, 2017). Figure 2.11 illustrates the general idea of the IoT architecture. It is composed of three layers namely, the perception, network and application layers.

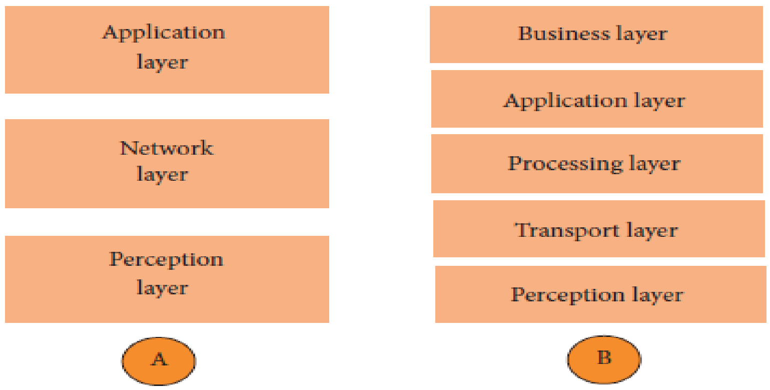


Figure 2.11: Architecture of IoT (A: three layers) (B: five layers) (Sethi & Sarangi, 2017)

- The perception Layer: it consititutes the sensors which are responsible for information gathering about the environment. It is also called the physical layer.
- The Network layer: it is responsible for interconnecting the smart devices, network devices and the servers. It propagates and processes sensor data
- The application layer: it delivers application specific services to the users.

2.5.1 Sensor-Based IoT System Architecture

A sensor-Based IoT architecture mainly consists of a set of sensors (deployed in "edge devices"), 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 (Saldanha, 2015). 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 are require 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 processing and transmission functions. It collects data from the sensors, decides what information is actionable business intelligence and forwards it to the cloud server via internet or cellular network connection. (4) Cloud Server which receives periodic signals from the gateway that indicate the status of the sensor network. The cloud can push down commands, configuration and software updates to the gateway and support application-level system management and analytics software. Figure 2.12 gives an overview of the sensor-based IoT architecture.

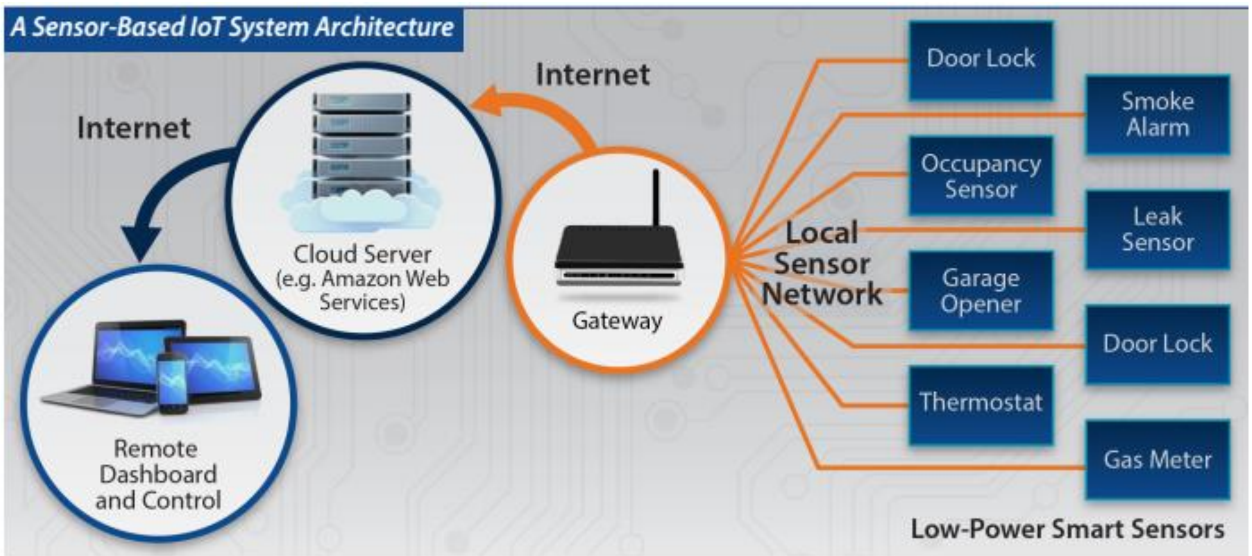


Figure 2.12: A Sensor-Based IoT System Architecture (Saldanha, 2015)

There are several means by which IoT solutions can be deployed depending on the context in which they are applied. However, by having a basic understanding of IoT architectures and functions makes it easy to visualize a range of possible deployments (Saldanha, 2015). Enterprises where sensor-based network communication have been deployed; have witnessed numerous benefits arising from the deployment. Some of the benefits include: (i) Reduced workforce costs associated with manual monitoring methods, (ii) Improved customer satisfaction and retention by providing highly proactive customer service without increasing costs (iii) Reduced equipment maintenance costs through early detection of equipment failures and device maintenance issues.

2.6 Applications used in fish pond water quality monitoring

Fish farmers have for long time been using manual methods to monitor fishpond water quality. The manual methods are tedious and error prone (Bokingkito & Llantos, 2017). Some farmers have disclosed that they do not monitor water quality of the fish ponds. Researchers have therefore attempted to develop technological solutions to counter the problem. This section presents the various applications that have been developed. The merits and the shortfalls of the applications were also analyzed.

2.6.1 IoT Enabled Real-Time Fishpond Management System

In their research, Idachaba et al., (2017) proposed the development of a system that would enable management of fish ponds 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 fish pond. The feeding mechanism comprised of a motor which is able to rotate so as 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 author however did not elaborate on the models and capabilities of the sensors used in monitoring the temperature and the PH. 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. An SMS service is expensive to implement because it attracts carrier charges with every SMS sent. Figure 2.13 illustrates the conceptual model they adopted to develop the system.

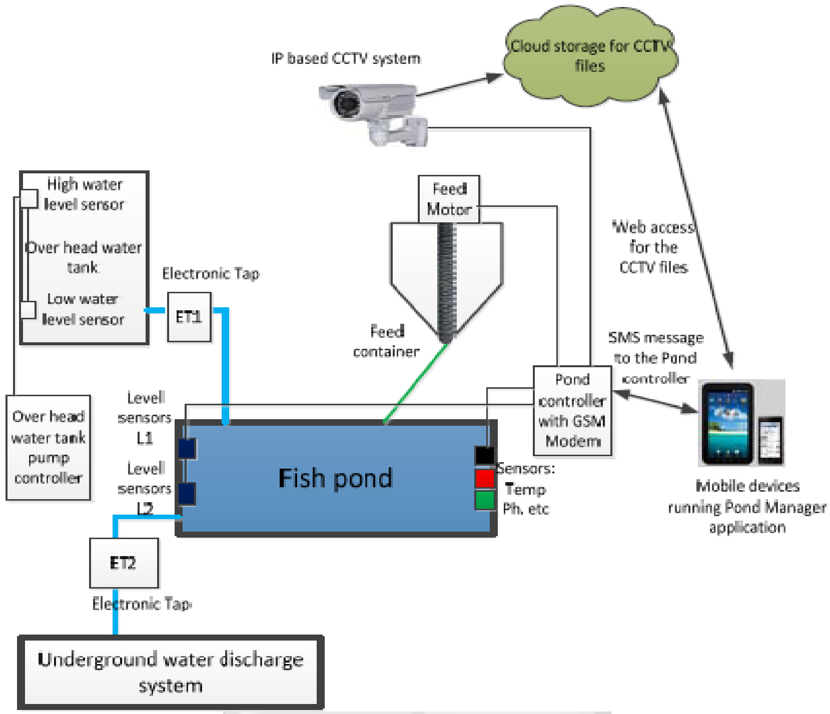


Figure 2.13: IoT Enabled Fish Pond Management System (Idachaba et al., 2017)

2.6.2 Water monitoring IoT system for fish farming ponds with WivityTM module

The system as proposed by (S & A., 2018) was to be implemented with a WivityTM Module which utilizes the LoRaWAN protocol. The LoRaWAN protocol enables low-powered communication devices to communicate with internet-enabled applications over long-range wireless connection. The system was to solve the problem of lack of internet accessibility in areas where fish ponds are remotely located. In their publication, (S & A., 2018) cited the hot-swapping capability and little technical know-how of the module as an advantage of implementing their system. The system had the capability of monitoring water level and temperature. It also utilized and RTC module to adjust lighting in the water.

Further, they acknowledged the lack of remote monitoring platform in their system as one of the limitations but noted however, that the system could be expanded to include the remote monitoring platform. The system also used a sound buzzer as the mode of notifying users of the change in the threshold which was also considered a limitation because the operators could not receive notification when they are far from site Figure 2.14illustrates the architecture they adopted for the development of the system.

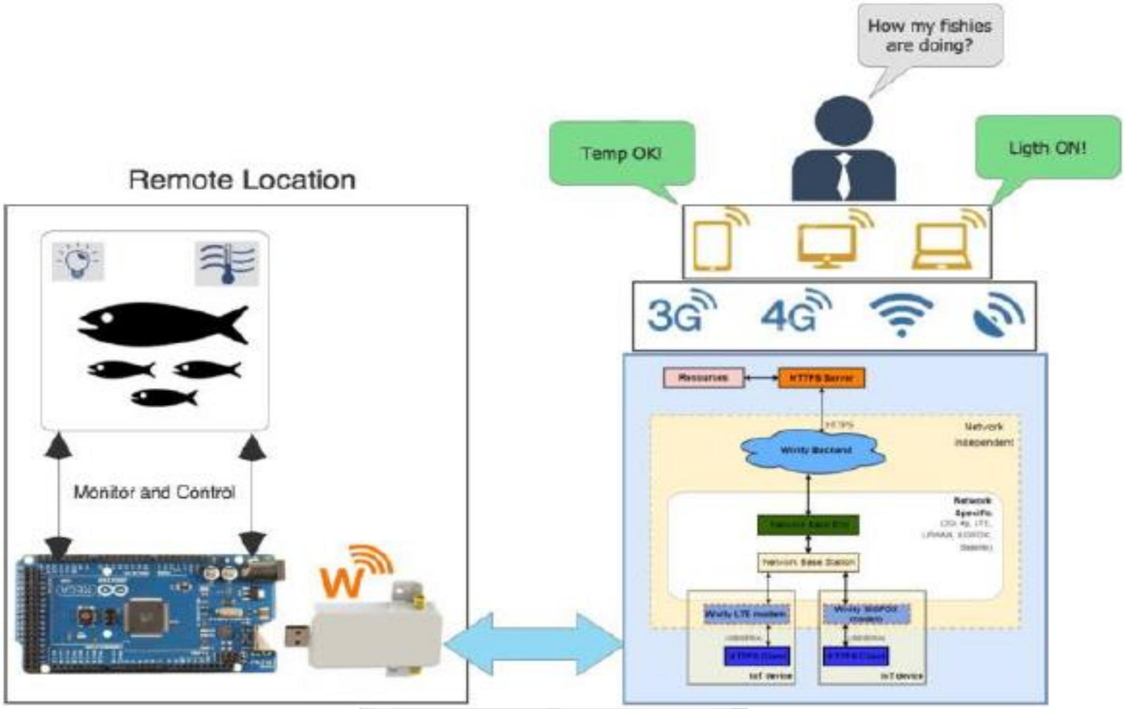


Figure 2.14 Water monitoring IoT system for fish farming ponds with Wivity module (S & A., 2018).

2.6.3 GSM based fish monitoring system using IoT

A system by (Sri, Nirosha, Priyanka, & Dhanalaxmi, 2017) was designed and developed to utilized the GSM technology to send Short message to alerts farmers on a display screen in case the quality of the fish pond water deteriorates. The system was composed of four modules namely: the input, evaluation, communication and output modules. Figure 2.15 illustrates the framework they adopted. The system monitored, temperature, PH scale level and dissolved oxygen level in the water. The author however did not give details of the sensor manufactures. The limitation to the system was that it did not provide a module where the famer could initiate an action to correct any anomaly in the water quality.

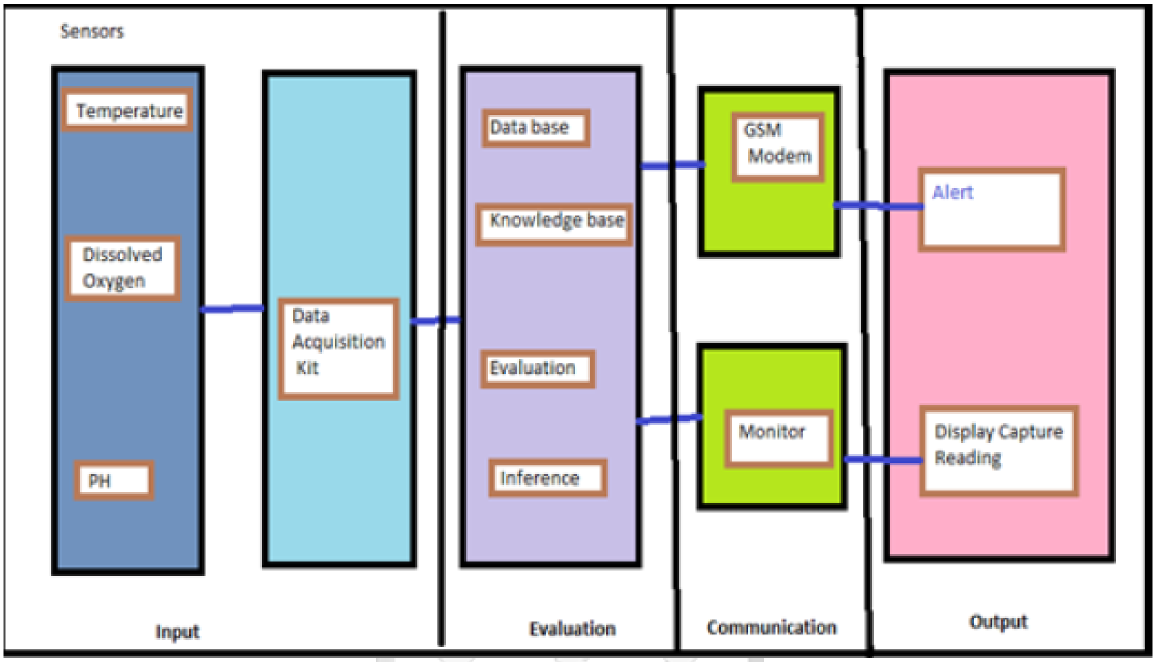


Figure 2.15: Framework for GSM Based Fish Monitoring System Using IOT (Sri et al., 2017)

2.7 Conceptual Model

From the literature review study, it is evident that fish pond culture is widely practiced in Kenya. It is noteworthy that finding the trade-off between increased inputs and higher yields can be better achieved by utilizing technology in monitoring water quality in the fish ponds. The crucial parameters in fish pond culture was identified and determined that monitoring these parameters on a real-time basis is necessary since they make the difference between life and death of the aquatic life and can determine the yield the farmer get from the fish. Various applications have been developed but fall short of some aspects. In Kenya, however, there lacks a system for aiding fish farmers in monitoring the aquaculture environment. The conceptual model of the proposed application was designed and adopted to feel that gap of the previous architectures as illustrated in figure 2.17

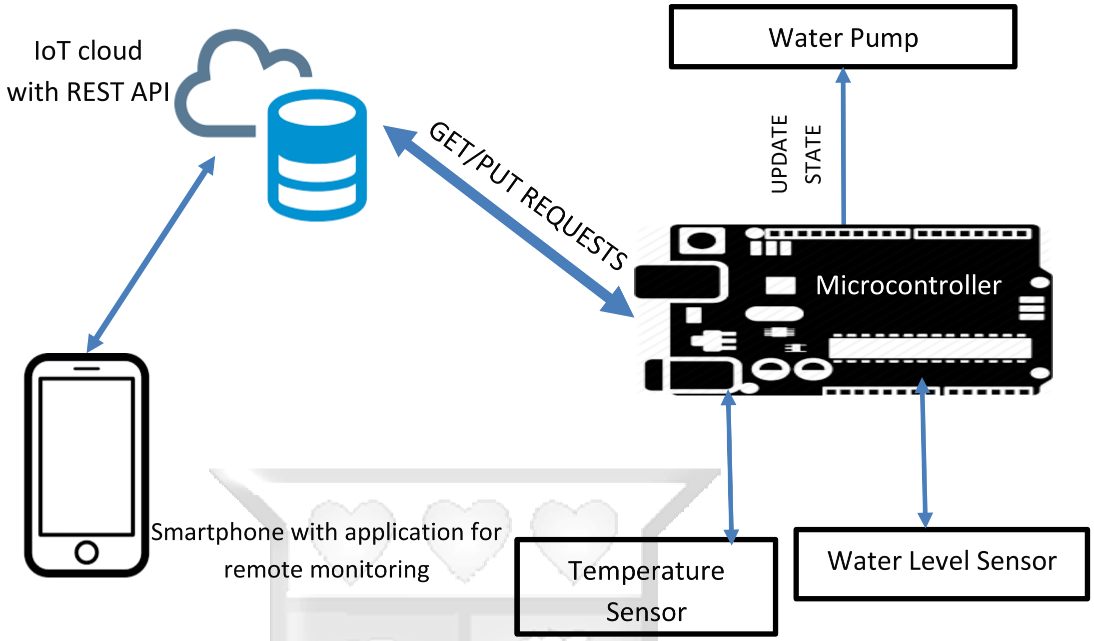


Figure 2.17: Conceptual Model for Real Time Fish Pond Water Quality Monitoring

The conceptual model proposed constitutes: Sensors for capturing water quality state through virtual pins, actuators which are in the form of relays and are responsible for manipulating devices such as the water pump, smartphone application cable of remote monitoring by displaying the water state and also issue user commands on the actuators a microprocessor which is responsible for executing a the programmed sequence of instructions embedded in it and finally a cloud infrastructure that contains a RESTFUL API whose function is to execute instructions obtained from the smartphone application.

Chapter Three: Research Design and Methodology

3.1 Introduction

This chapter presents the methodical approach that was used in the research. It discusses how the research was designed and the tools and techniques used to gather data for the development of the application based on the discussions in chapter one and two.

3.2 Research Design

A research design serves as the architectural blueprint of a research project, linking design, data collection, and analysis activities to the research questions and ensuring that the complete research agenda will be addressed (Bickman & Rog, 2009).In this research, a participatory action research (PAR) design was adopted. In this type of research, the participants define their problems and participate in designing the solution to the problem (Rubin & Babbie, 2011). The purpose of this research was to provide a solution to the water quality monitoring problem by developing a smartphone-based application that would aid fish farmers in monitoring the fish pond water quality and was simple to operate. Figure 3.1 illustrates the applied research planning approach

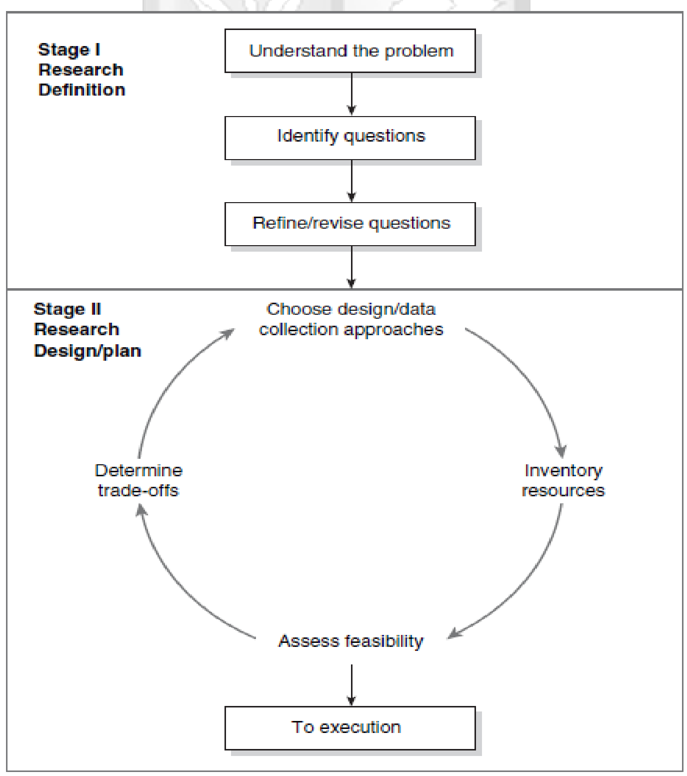


Figure 3.1: Applied Research Approach (Bickman & Rog, 2009)

3.3 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. The methodology involves user's participation throughout the development process necessitated by the need to evaluate the outcome of each cycle (Córdova, Troncoso, Díaz, Palominos, & Canete, 2016). Figure 3.1 shows a summary of the RAD process.

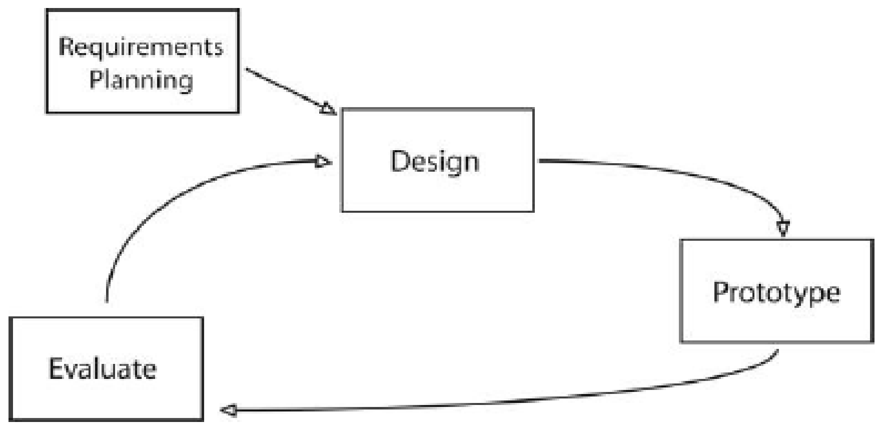


Figure 3.2: Rapid Application Methodology (Córdova et al., 2016)

The methodology was incorporated in stage II as depicted in figure 3.1. Various 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 aspects that require monitoring. Interviewing the operators of the fish ponds also provided information on what should be incorporated 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.

3.3.1 Data collection instruments

The research deployed both primary and secondary data. The data formed the basis of developing the various application components. The techniques involved were:

i. Literature review from various sources e.g. thesis, government report, conference papers and journal articles formed the bulk of secondary data sources. The sources mostly provided information on the water quality aspects that should be monitored, the challenges in monitoring water quality and the deficiencies in the current architectures used in monitoring water quality. They provided authoritative information regarding aquaculture.
ii. Questionnaires: the questionnaires were structure in manner that they would provide information regarding the user requirements and usability of the proposed application. The questionnaires were administered both online and on site. On site administration was necessary in instances where farmers were not literate enough to fill the questionnaires especially where the farmers were not able to fill them online. The questionnaires were administered in two stages i.e. before the development of the application to gather the requirements and after the development so get feedback on the functionality and usability.
iii. Qualitative interview: this is a type of interview where the interviewer has no specific preset question that are 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 fish ponds are monitored.

3.4 Data Analysis Presentation

A quantitative data analysis and presentation was done using Microsoft Excel. Data gathered from questionnaires was downloaded in the excel sheets and were graphically presented in the form of pie charts.

3.6 Target Population and Sampling

The research employs the purposive sampling technique. This technique was chosen because the researcher had in mind the type and quality of respondents, he wants to obtain information from. The researcher adopted the (Krejcie & Morgan, 1970) table (**see appendix C**) to obtain a sample size of 108 based on the total population of 108 farmers.

3.7 Ethical Consideration

The research solicited the help of human respondents hence the requirement for ethical considerations. According to (Rubin & Babbie, 2011) the respondent's participation in a research should be voluntary and should also be based on consent. The ethical issues considered were confidentiality and consent. Voluntary participation was achieved by guaranteeing confidentiality. Confidentiality entails concealing the participant's personal data from the public. To achieve confidentiality, the participants were not required to provide their personal information during the process of data collection. Consent was obtained by explaining to the participants the purpose and the importance of the research.

3.8 Experimental setup

Figure 3.3 Illustrates the experimental setup that was adopted.

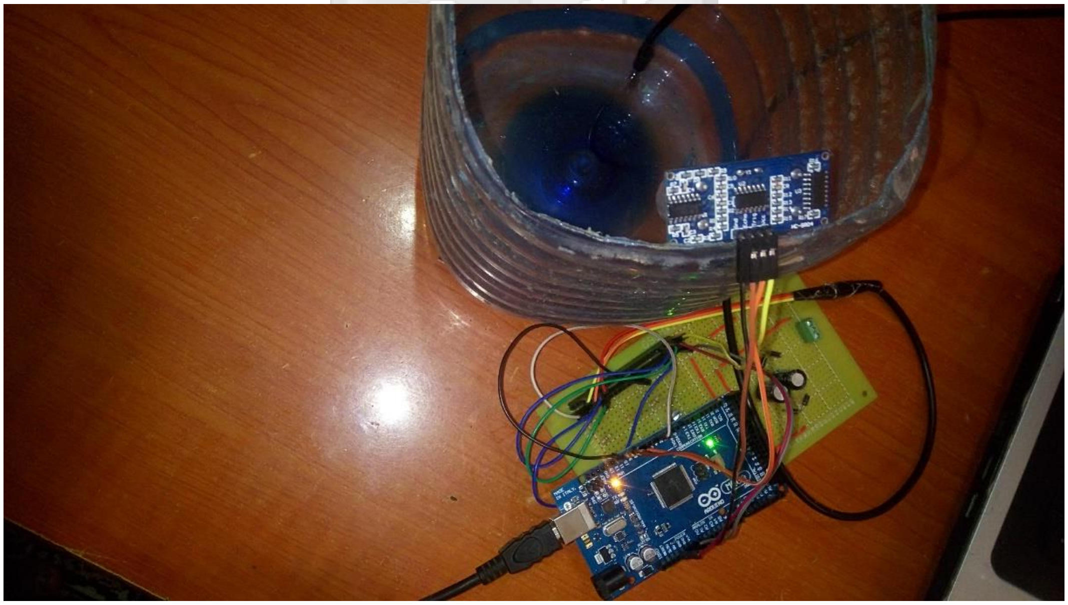


Figure 3.3: Experimental Setup

Chapter Four: System Analysis and Design

4.1 Introduction

This section discusses the 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 analysis entails; understanding the current situation, identify improvements, and finally defining the requirements of the proposed solution.

4.2 Data Analysis and Results

Data collected from the questionnaires and interviews were analyzed in order to capture the farmers' and the various stakeholders' views on the current methods of aquaculture water monitoring and suggestions of how the methods can be improved.

4.2.1 Years of fish farming experience

The researcher sought to know the fish farming experience of the respondents. This would aid in justifying the application of the recommendations from the Respondents. Figure 4.1 indicates that 54% percent of respondents had more than five years' experience in fish harming, 18% had less than 5 years of experience while 28% had less than one-year experience in farming.

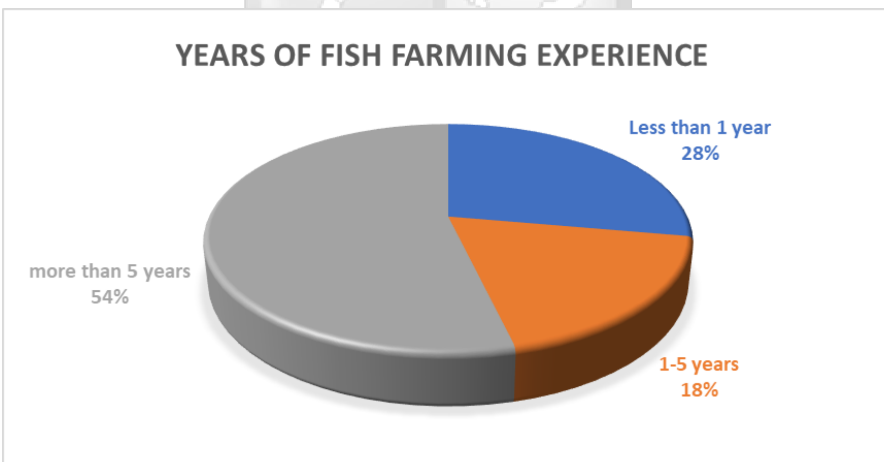


Figure 4.1: Farmers experience in fish farming

4.2.2 Importance of fish pond water quality monitoring

It was important for the researcher to determine the degree to which the respondents agreed that water was an important aspect in fish pond monitoring as this would form the basis of developing the model. As revealed in figure 4.2 67% strongly agreed it is important to monitor water quality, 7% strongly agreed it is important to monitor water quality while 26% had a neutral opinion on the importance of water quality monitoring.

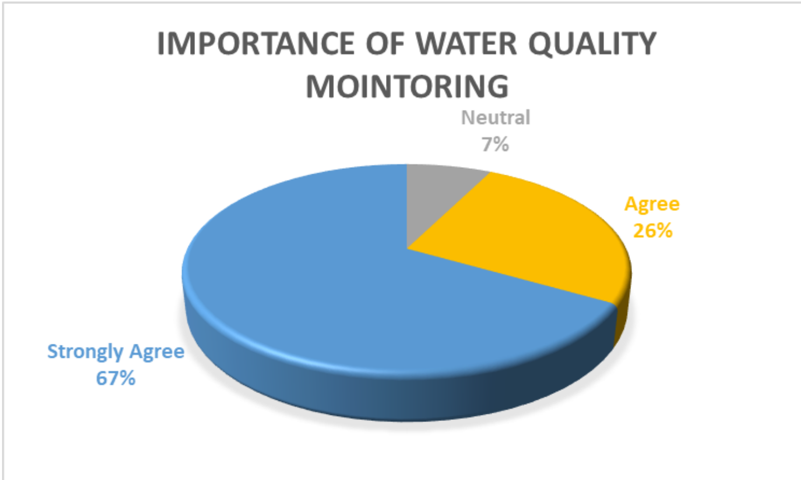


Figure 4.2: Importance of water quality monitoring

4.2.3 Frequency of water quality check

Once it was determined how important water monitoring is, it was necessary to determine how frequent the respondents checked the water quality so as to reveal the challenges if any, they are facing during the quality check. As revealed in figure 4.3, 55 % of the respondents checked the water quality of the ponds once a day. 28% once a week while 17% rarely check the eater quality. From the analysis, it is evident that majority of the respondents' made efforts to check on water quality but it was less frequent. From the interviews, the respondents revealed that is was difficult to constantly monitor the water quality due to inaccessibility of measuring equipment and lack of technical know-how in measuring the parameters.

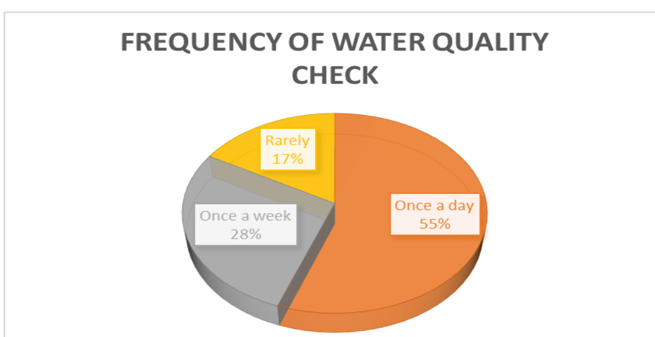


Figure 4.3: Frequency of water checks

4.2.4 Technology usage

The knowledge on the technology usage was important because it gave indications as to how the user interface was to be designed in terms of complexity. This would also determine the user training requirements. Figure 4.4 illustrates that 69% of the respondents were skilled while 31% were very skilled

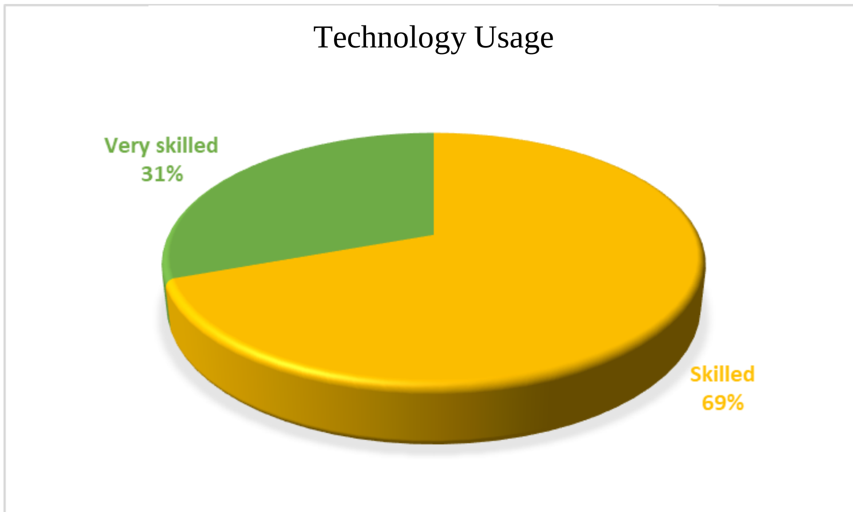


Figure 4.4: Technology Usage

4.2.5 Timeliness of the current process of water monitoring

The performance of the current methods would justify the need for a smartphone-based model for monitoring the fish pond. Figure 4.5 illustrates that 93 % of the respondents strongly disagreed that current processes gave instant status report on the water quality parameters and an additional 7% disagreed. Judging from the analysis therefore, it was important that a real time monitoring model was necessarily so as to provide instant status

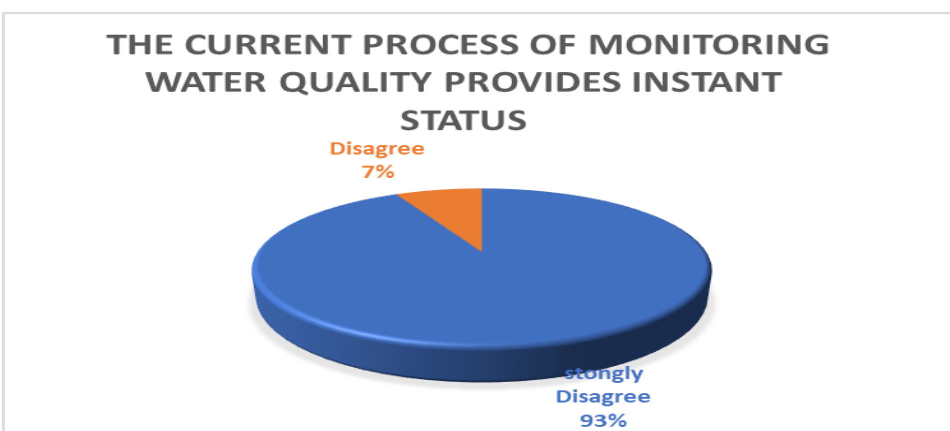


Figure 4.5: Timeliness of current process

4.2.6 Recommendation of a water quality monitoring application

As illustrated in figure 4.6 77% strongly agreed that a smartphone-based water quality monitoring application would make water quality monitoring easier, 17% agreed and 6% were neutral.

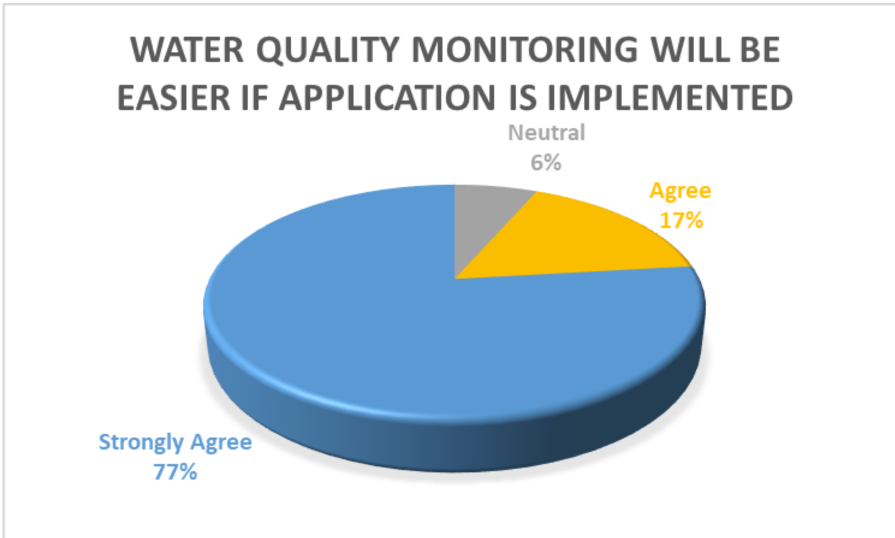


Figure 4.6: Recommendation of a smartphone-based water quality monitoring application

4.3 Application User Requirements

Based on the data collected from the questionnaires and interviews, the users preferred an application that will offer (a) timely updates on the water quality parameters, (b) user interface with menus that is easy to navigate, (c) presentation of data that is easy to interpret, (d) reports on historic data for current and future decision making

4.3.1 Application Functional Requirements

The functional requirements provide descriptions of how the application should react to particular inputs and the behavior of the application given a certain situation. The application therefore:

- shall Sense the water quality parameters through specific sensors.
- Generate reports on user request.
- Shall notify the users when a certain thresh hold are met.
- Display the correct status of the parameters.
- Shall register authorized users.

4.3.2 Application Non-Function Requirements

The non-functional requirements mainly entail the quality aspect of the application. The requirements are:

- Performance: the application should be able to display timely and accurate data.
- Scalability: it should have provision for adding more sensors in the future.
- Manageability: it should be easily managed by the users.
- Reliability: It should read the parameter values at all times.
- Security: Should not allow unauthorized access

4.4 Application Architecture

The system architecture is modular and gives an overview of how the various modules shall interact. As depicted in figure 4.7. The modules are described as follows:

- **Aquaculture water**: this is the fish pond where the fish is reared. It shall comprise of 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.
- **IoT Cloud server:** the cloud server analyzes the data received and acts per the predefined conditions.
- **Application:** the mobile application provides a means of visualizing the data on the server and provides and interface to the user for decision making.
- **Actuators:** the actuators act upon the aquaculture environment based on instructions received from the IoT cloud server.

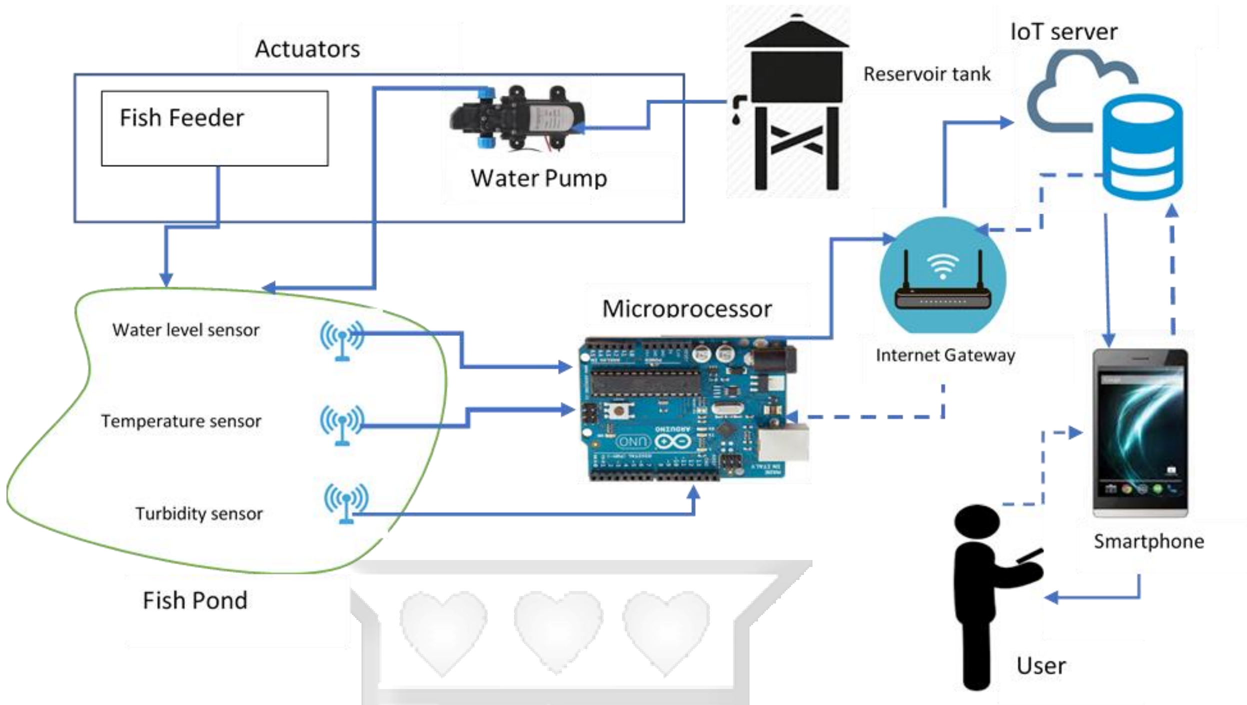


Figure 4.7: IoT-Based Water Monitoring System Architecture

4.5 Process Modelling

A software process model is an abstract representation of the architecture (Acuña & Belgrano, n.d.). The models illustrate how different modules of the software interact.

4.5.1 Context Level Diagram

A context diagram is a high-level diagram that defines the boundary between the system, or part of a system, and its environment, showing the entities that interact with it. The application has four main entities that interact with it namely: the users, sensors and actuators. The main process is to monitor the water quality. The users are able to view the status via a graphical user interface and perform actions like feeding the fish when the conditions are favorable. Figure 4.8 illustrates the context diagram.

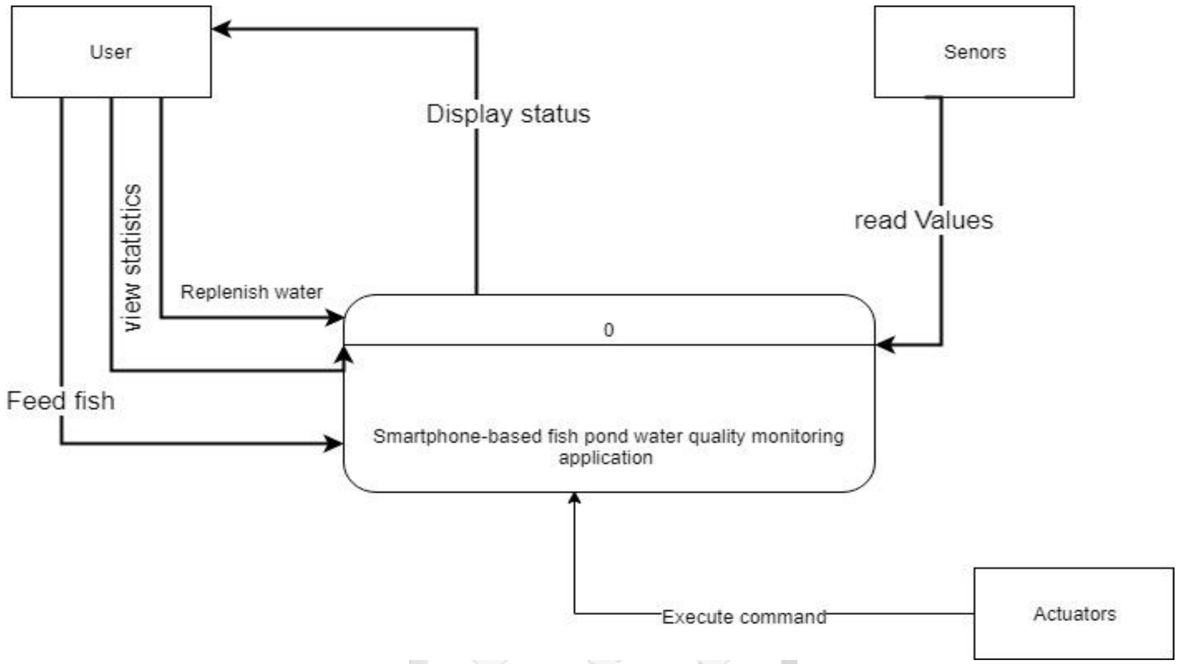


Figure 4.8: Context Level 0 Diagram

4.5.2 Level 1 diagram

A level 1 diagram breaks the context diagram further into sub-process. The processes are illustrated in figure 4.9

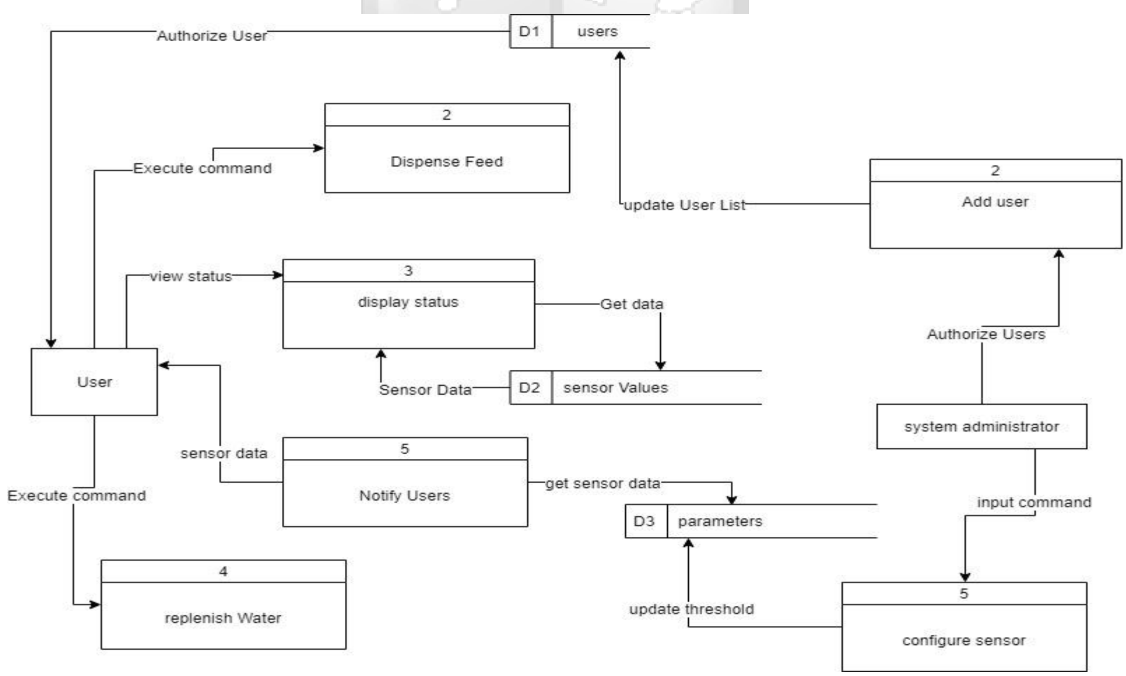


Figure 4.9: level 1 diagram

4.5.3 Use case modelling

Use case is a description of a set of roles by actors which yield observable useful results to the actor. A use case diagram gives a graphic representation of how different elements of a system interact. Figure 4.10 shows the roles different actors play in the fish aquaculture monitoring system.

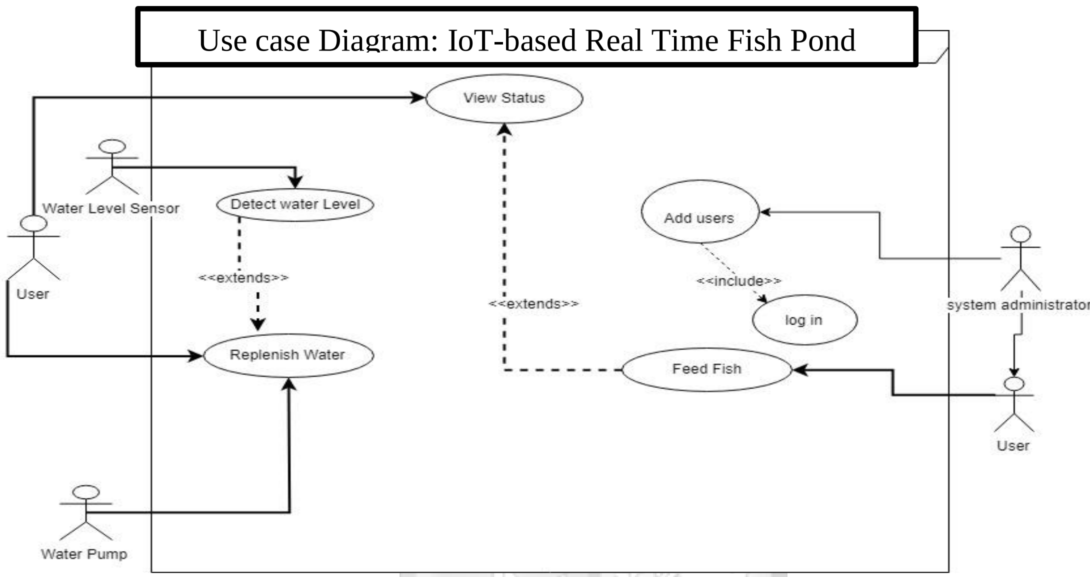


Figure 4.10: Use Case Diagram for IoT-based Real Time Fish Pond Water Quality monitoring

4.5.4 Use Case Descriptions

The authorized users of the system must be able to successfully login to the application in order to monitor the water quality. The add user use case as describes the scenario for registering a user as illustrated in table 4.1.

Table 4.1: Add User Use Case

Title:	Add User
Description:	Authorized users added to the application
Primary Actor:	System administrator
Precondition:	The administrator must be logged in
Post Condition:	User are successfully added
Main success scenario:	Users are able to access the system

Table 4.2 shows the use case for detecting the water level in the pond. The sensor must be on so that it can detect the water level. The Sensor then updates the readings that will be transmitted to the cloud server. The cloud server shall then display the values via the application's user interaction interface.

Table 4.2: Detect Water Level Use Case

Title:	Detect Water Level
Description:	Ultra-sonic Sensor detects the water level and updates reading
Primary Actor:	Ultra-sonic Sensor
Precondition:	Sensor is on
Post Condition:	Server Updates reading
Main Success scenario:	1.sensor Data is transmitted to the cloud server 2. Sensor data is displayed

Table 4.3 shows the use case for detecting the turbidity in the pond. The sensor must be on so that it can detect turbidity. The Sensor updates the readings that will be transmitted to the cloud server. The cloud server shall then display real time status of the water turbidity.

Table 4.3: Detect turbidity Use Case

Title:	Turbidity Level
Description:	Turbidity Sensor detects the water level and updates reading
Primary Actor:	Turbidity Sensor
Precondition:	Sensor is on
Post Condition:	Server Updates reading
Main Success scenario:	1.Sensor Data is transmitted to the cloud server 2. Sensor data is displayed

The replenish water use case describes the event for turning on the water value on the water pump given certain conditions such as low water levels as described in Table 4.4. The user has the option of remotely switching on the value or the system can automatically act on behalf of the user. The status of the water pump switch is the displayed on the application's control sensor menu.

Table 4.4: Replenish Water Use Case

Title:	Replenish Water
Description:	Water pump can add water to fish pond
Primary Actor:	Water pump
Precondition:	Water pump inlet valve must be on
Post Condition:	Water level adjusted
Main Success scenario:	1.Sensor Data is transmitted to the cloud server 2. Sensor data is displayed

Given favorable conditions such as the water temperature? The user can remotely feed the fish by activating the feed dispenser. Tables 4.4 describes the dispense feed Use Case. The fish feeder broadcast the feed pellets to the pond on user's command.

Table 4.5: Dispense Feed Use Case

Title:	Dispense Feed
Description:	Fish feeder broadcasts food pellets
Primary Actor:	Fish feeder
Precondition:	Fish feeder is on Water temperature must be optimal
Post Condition:	Server Updates reading
Main Success scenario:	1.Sensor Data is transmitted to the cloud server 2. Sensor data is displayed

4.5.5 Sequence diagram

A sequence diagram illustrates the sequential interaction between objects. Figure 4.3 illustrates how the various components of the application shall interact. The proposed model was composed of a sequenced interaction between various sensor and the commands which the user inputs. The outputs of the commands which are mainly: the sensor values and the actuator actions such as the water pump. The user has to initially log in to the system then from the menu options presented in the graphical interaction interface, the user decides which action he wants to take. The ultimate goal of monitoring the water quality in the fish pond is to enable the user to act proactively in the event the are any changes in the recommended parameter thresholds. This is demonstrated in the operate command sequence.

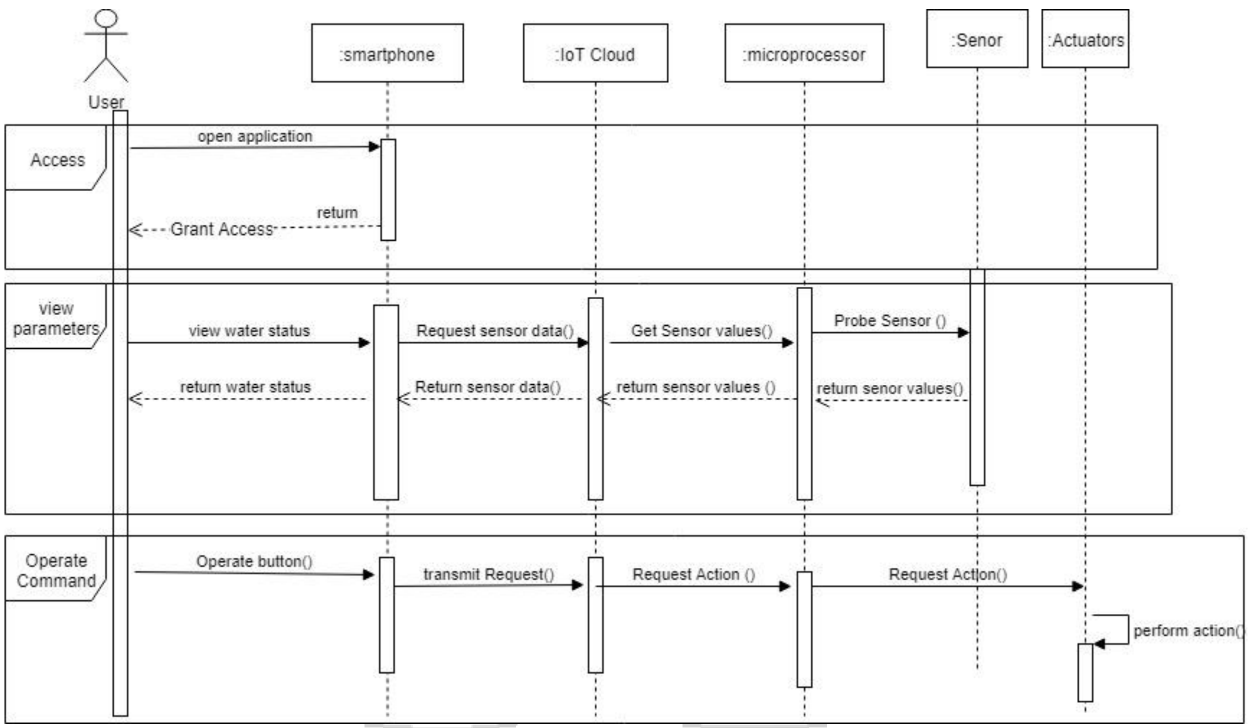


Figure 4.11: Fish Pond Water quality monitoring process Sequence diagram

4.5.6 Activity Diagram

An activity diagram illustrates the program flow of control. It was used to construct the executable codes for the application. It shows how the various process are interlinked, the input and the output of each process. Figure 4.5 illustrates the activity diagram for the application.

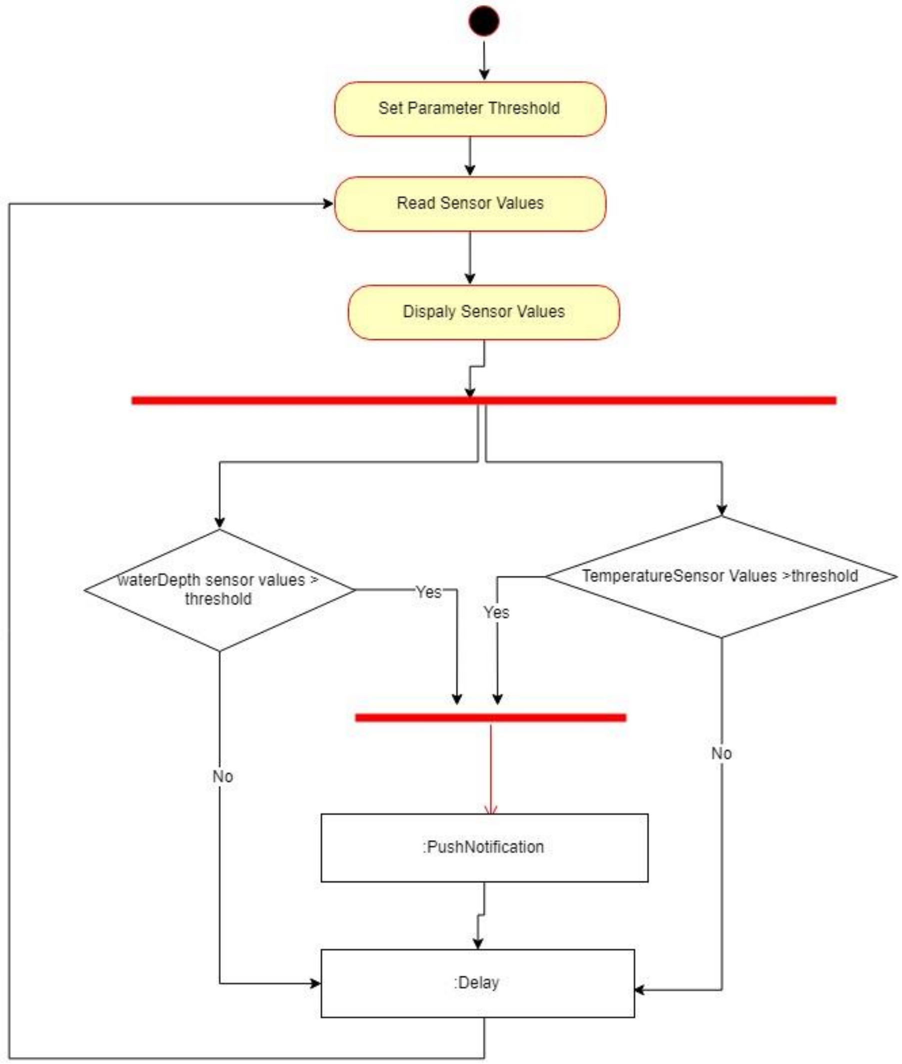


Figure 4.12: Activity diagram for fish pond water quality monitoring application

Chapter Five: Implementation and Testing

5.1 Introduction

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.

5.2 Application Hardware and software Requirements

Table 5.0 and table 5.1 lists the range of hardware and software that was used. The details of the sensor capabilities are illustrated in appendix E.

Table 5.0: Hardware requirements

HARDWARE	SPECIFICATION	FUCNTION
PCB Printed Circuit Board Prototype	10cm x 22cm	Support the soldered electric components
Solder wire	0.3mm core	Joining electical components
Solderig gun	working volatge AC220V / 50Hz	Heating solder
Male/female jumper cables	20cm	Provide connection between two electic components
HC-SR04 ultrasonic sensor	5V powersupply, <2mA current, range distance2cm-500cm	Determine distance between two points
SKU: SEN0189 turbidity Sensor	Operating Voltage: 5V DC,Insulation Resistance: 100M (Min)	Measure turbidity levels
DS18B20 temperature sensor	PVC jacket,(±0.5°C precision	Measure water temperature
Water Pump	Operating Voltage: 12V	Pump water
Smartphone	Android OS, 2GB RAM	Provide platfom for installing application
Arduino UNO R3	dual-inline-package (DIP) ,ATmega328,	Control the sensors
Laptop	windows 10, 8GB RAM, coi7 CPU, 500GB harddrive	provide console for microprocessor configuration,act as internet gateway

Table 5.1: Software requirements

SOFTWARE	SPECIFICATION	FUNCTION
Arduino IDE (Intergarted Digital Environment)	Version 1.6 or Higher	Used to write and upload code to microprocessor
Blynk App	Latest Verion	Create Graphical User interfaces for visualization, provide communication between sensors bylnk server, provide hardware libraries
Android OS	Version 4.2 or higer	provide platform for installing Blynk app
Client Operating System	Microsoft Windows 10 pro	provide platform for installing IDE

5.3 Hardware Assembly

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.

5.3.1 Circuit design

Figures 5.4, 5.5 show sample sketches of temperature sensor, ultrasonic sensor respectively and how the sensors were connected to the microprocessor. The color coding is illustrated in appendix D

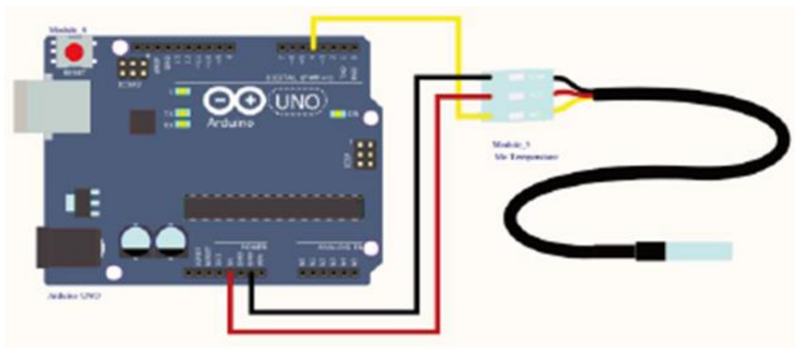


Figure 5.4: Temperature Sensor wiring

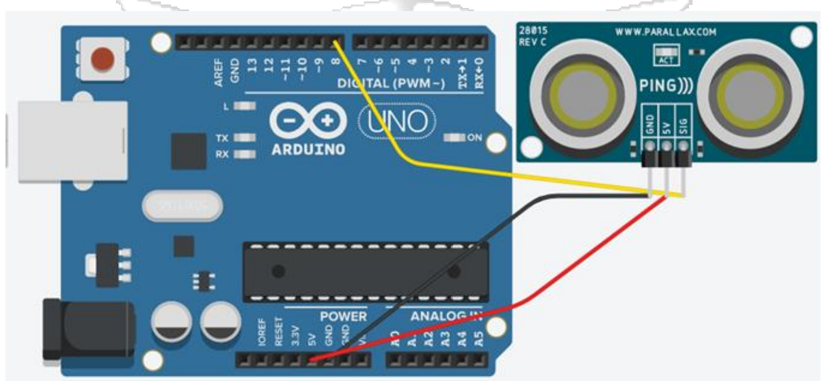


Figure 5.5: Ultrasonic Sensor wiring

5.4 Software Configuration

This research employed the Blynk platform as a rapid prototyping tool for the application development. Blynk is basically mobile application that is made up three components:

i. Blynk App – enables one to create interfaces for projects using various widgets.

ii. Blynk Server - responsible for all the communications between the smartphone and hardware.

iii. Blynk Libraries – contains libraries for a host of hardware platforms. They enable communication with the server and process all the incoming and outgoing commands.

5.4.2 Initial configuration

The creator of the application i.e. the system administrator first downloads the blynk application for Google's play store. Figure 5.6 shows sample configuration forms for configuring an application. Authentication tokens for secure application access are generated and sent to the email registered by the administrator.

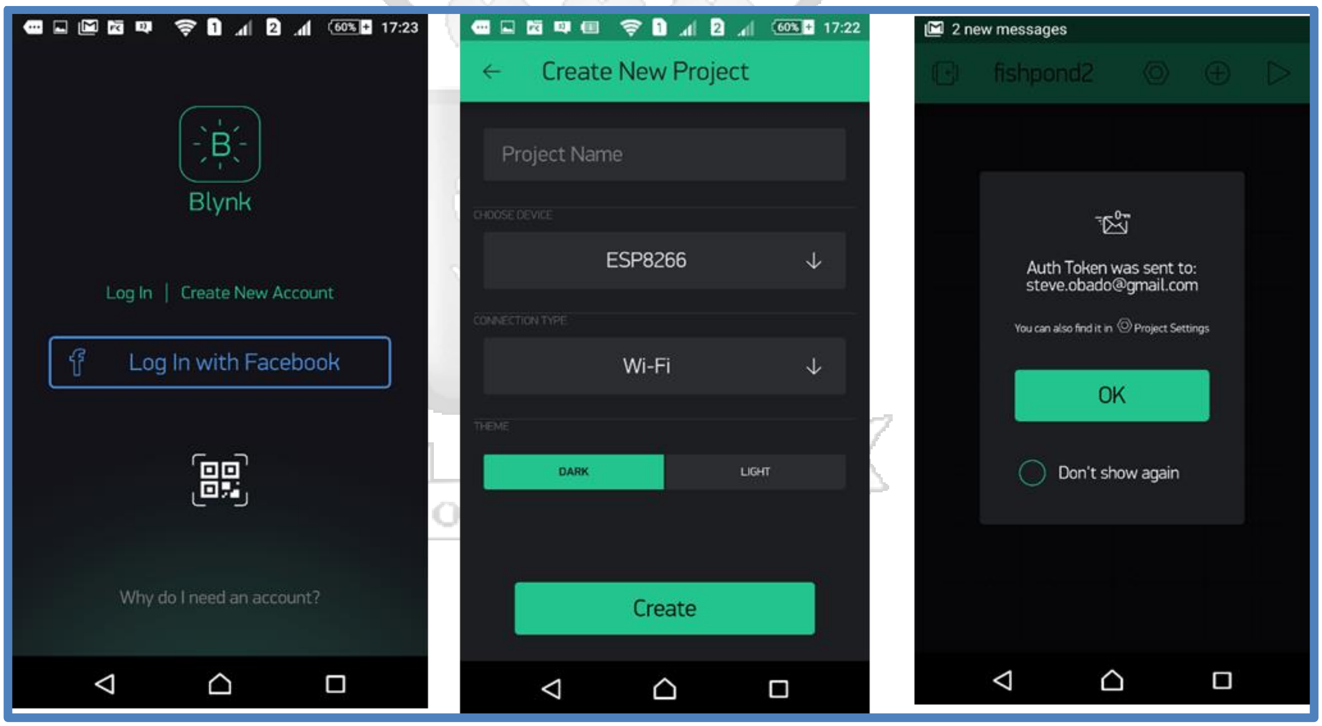


Figure 5.6: Sample application configuration forms

5.4.2 Dashboard Design

The application dash board is the graphical user interface that the users shall use to interact with application components. The application provides widgets which the administrator can add according to the use. Figure 5.7 shows sample forms for design dashboard. The dashboard contains menus and widgets which users can use to navigate the application

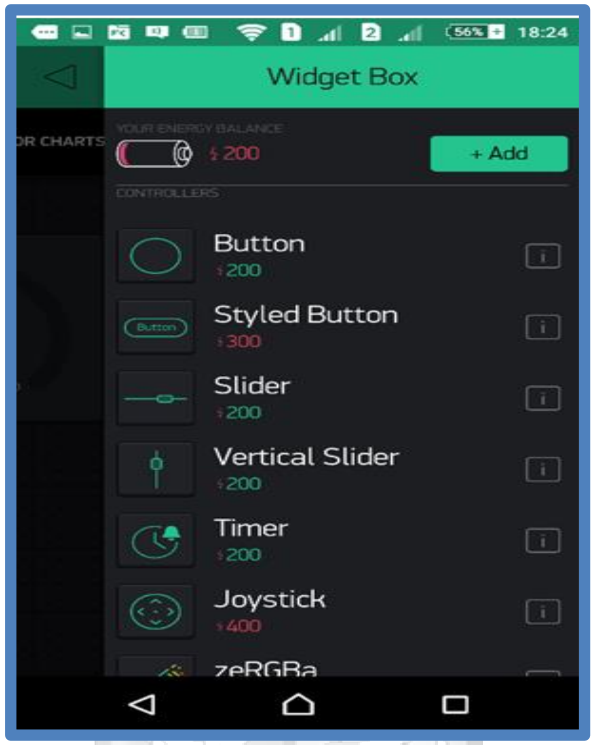


Figure 5.7 sample dashboard

5.4.3 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 5.8 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 which will continuously probe the sensors in a predefined interval. Figure 5.9 shows a sample execution code for measuring the water level. The blynk app executes a function that operates in PUSH mode which is used to update the water level widget.

```
//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 5.8: Pseudo code for program execution

```
void loop() {
// Clears the trigPin
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
// Sets the trigPin on HIGH state for 10 micro seconds
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
// Reads the echoPin, returns the sound wave travel time in microseconds
duration = pulseIn(echoPin, HIGH);
// Calculating the distance
distance= duration*0.034/2;
Blynk.run();

Blynk.virtualWrite(V1, distance);
```

Figure 5.9 sample code for water level measurement

5.5 Algorithm Implementation and Validation

The algorithm is implemented in a sequence of commands from initialization process to the notification. During initialization, the thresholds for the parameters are set and any deviation from the set threshold triggers an alert which is sent to the users' smartphone. Figure 5.14 shows the sample code for threshold criteria and the functions that display notifications to user. Further to ensure that the correct information is transmitted by the application, data validation mechanisms were incorporated in the code. Figure 5.8show an example of how the application should respond should respond when the user enters an incorrect password. Further, figures 5.15 illustrates the notifications displayed when the threshold criteria are achieved.

```
Blynk.run();
if (Celcius > 30){
  Blynk.notify("CHECK WATER TEMPERATURE!");
  }
Blynk.virtualWrite(V4, Celcius);
Blynk.virtualWrite(V1, distance);
if (distance > 15){
  Blynk.notify("CHECK WATER LEVEL!");
  }
//Blynk.virtualWrite(V1, distance);
delay(1000);

}
```

Figure 5.6: Sample code for threshold criteria

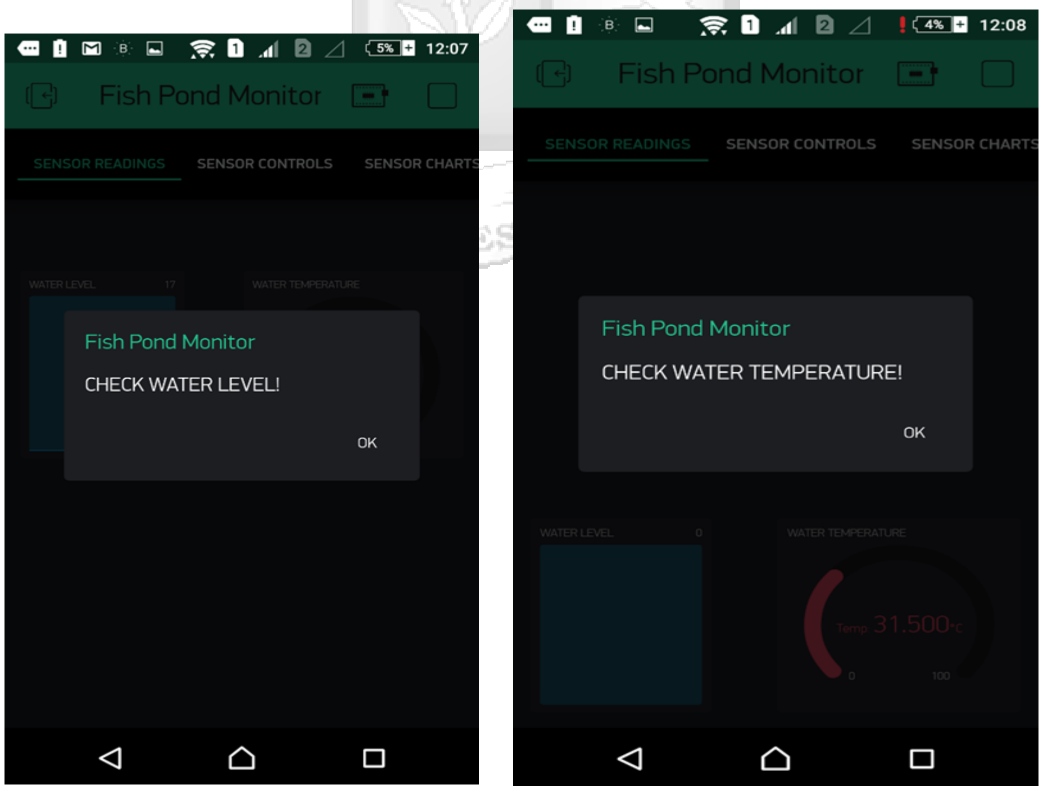


Figure 5.10: Notification for water level and temperature thresholds

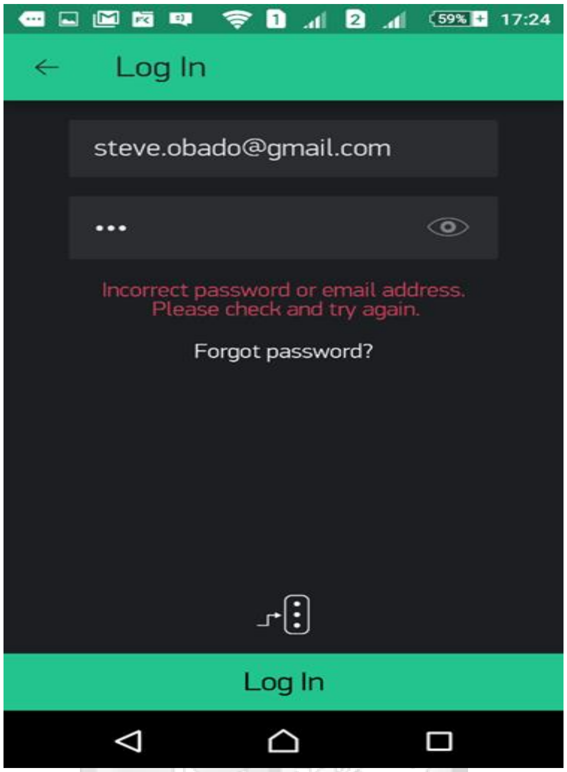


Figure 5.11: Incorrect password input

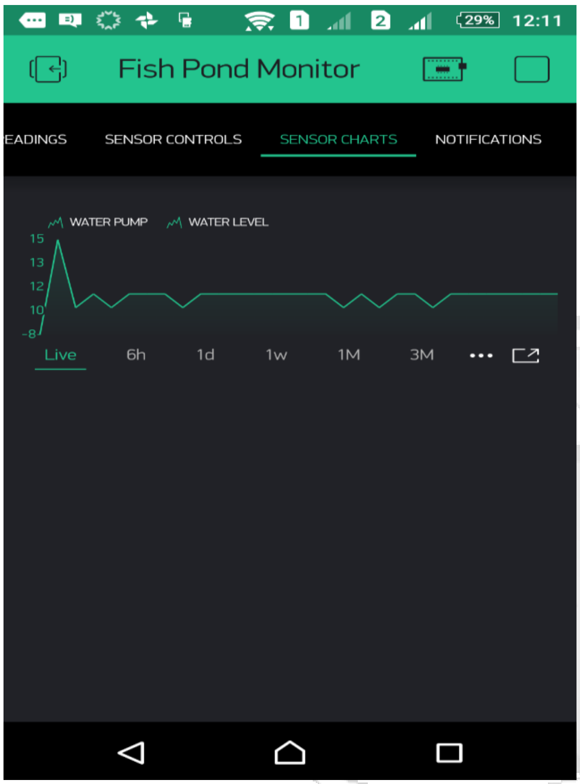
5.6 Application Testing

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 score card in table layout as illustrated in table 5.1

Table 5.1: Application Test

	Application Tests Score Card		
S/No.	**FUNCTION**	**EXPECTED RESULT**	**SCORE**
1	Ultra-Sonic Senor measure water level	Accurately measure the level of water in the pond	PASS
2	Water Level Widget	Accurately display the level of water in the pond	PASS
3	Temperature sensor to measure water temperature	Accurately measure the temperature of water in the	PASS
4	Water Temperature Widget	Accurately display water temperature	PASS
5	Water pump Switch	Switch the water pump on or off	PASS
6	Sensor charts	Display sensors historical data	PASS

Figures 5.12 illustrates a test sample form of historical data for water level represented in a chart. The user is able to know the trend of the water level during a certain period and this would aid in investigating any incidences that might arise due to water level fluctuations. Figure 5.13 illustrates a test sample display for real time water level status



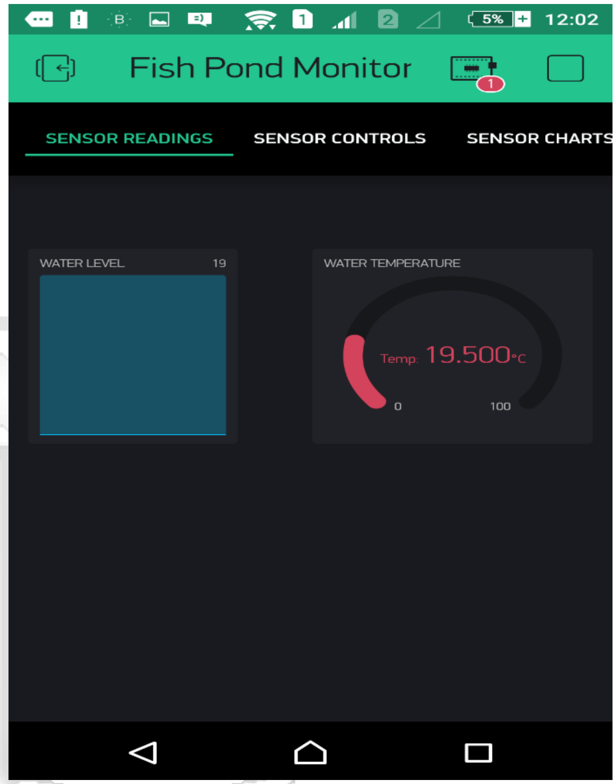


Figure 5.12: Water level history data display *Figure 5.13: water level and temperture status*

Chapter Six: Discussions

6.1 Introduction

In this section we shall discuss the findings of the implementation of the real time model fish pond 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 the water level. 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 threshold 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 stakeholders 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 wasteage.

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. Pie charts was the researcher's instrument of choice for the analysis of the respondents' feedback.

6.2 Graphical User Interface

The objective of the graphical user interface was to enable the users to navigate the application and interpret the information displayed with ease. Figure 6.0 illustrates the respondents' feedback on the usability of the system. 44% strongly agreed that the graphical user interface was easy to navigate, 40% agreed and 16% were neutral.

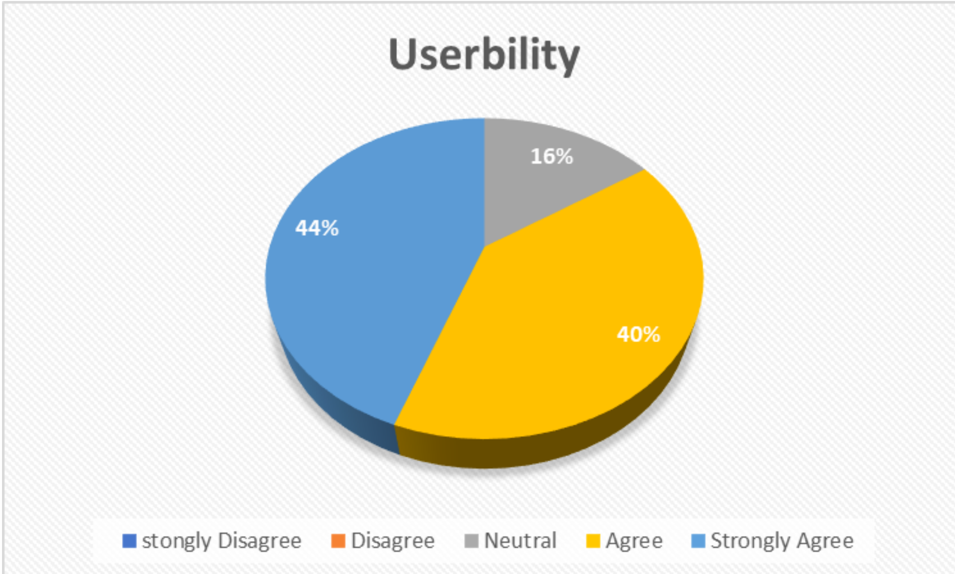


Figure 6.0: Model Usability.

6.3 Reliability of the model

The users recommended that they wanted a model that would provide real time status of the water quality. Figure 6.1 illustrates the respondents' feedback on the model's ability to display real time status. 67% of the respondents agreed that the system relayed real time status on the water status, 22% strongly agreed whereas 11% were neutral

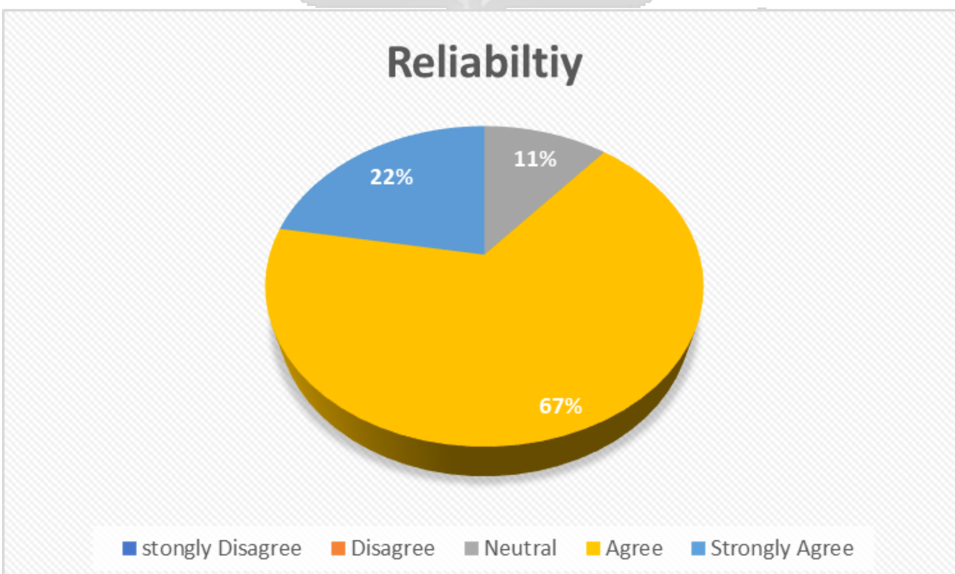


Figure 6.1: Application Reliability

6.4 Performance

Performance was one of the key factors to consider while developing the application. The main question was, does the system function the way it was designed to function? The analysis presented in figure 6.2 illustrates that 78% of the respondents agreed that the system performed as per the design while 22% agreed.

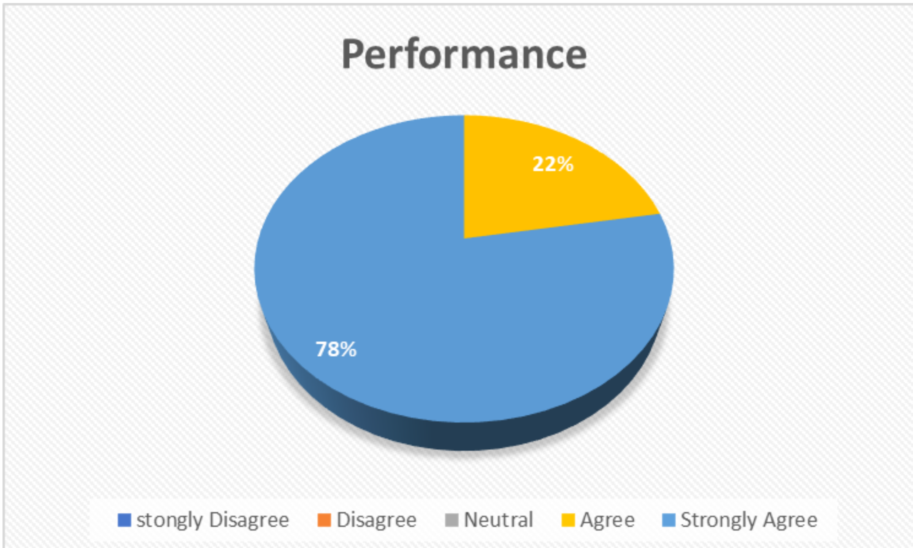


Figure 6.2: Application's performance

6.5 Relevance of the model

One of the motivations of developing the model was the inability of the current methods of water quality to relay status on time. The popularity and the skill level of the users of smartphone was therefore key in actualizing the objective of the model. The respondents were asked whether they would use the application to monitor the fish pond and their response were summarized in figure 6.3. 67% strongly agreed that they would use the application to monitor their fish pond water quality, 22% agreed while 11% had a neutral opinion.

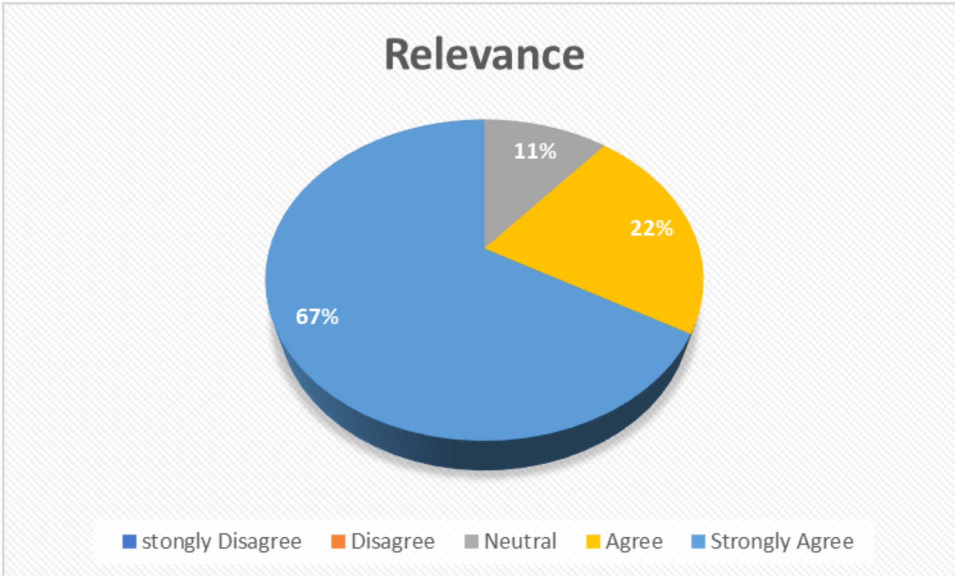


Figure 6.3: Relevance of the model

6.6 Application Limitations

During the study period it was noted that there were areas where fish ponds that located in remote areas with no electrical connectivity and this proved to be an obstacle when it came to powering the devices. Though the devices can be battery powered, the continuous supply of power was not guaranteed because the was no means of recharging the battery. The powering of the device in remote areas was not in the scope of this model development.

Chapter Seven: Conclusion and Recommendations

7.1 Conclusion

Fish farming has been identified as the viable solution for stocking fish in this era where the wild fish stock from rivers and lakes are declining due to environmental pollution that result in fish kills. The farming of in facilities such as ponds can guarantee to some level, a conducive environment where the fish can survive to maturity and thus contribute to the country's food security. The fact that fish live in water and respond quickly to environmental changes means that it is important to monitor the water quality to guarantee survival.

In this study it was observed through the data collection and interviews that most fish farmers or those responsible for monitoring the fish rarely monitor the status of the water for changing conditions. This has resulted to loss and has made fish farming an expensive venture because the farmers invest in expensive inputs such feeds that do not translate to profits. Real time monitoring and timely intervention to these environmental changes is therefore key to providing the solution to this problem.

In chapter two, the effect of the water quality aspects on the fish was discussed and the shortcomings of the existing fish pond water quality aspects were also discussed. The researcher was able to successfully address the shortcoming of the models by proposing and testing an alternative model. The researcher was bias on the use of a smartphone for real time remote monitoring because of the ubiquitous nature of the smartphones. The use of a smartphone was also based on the studies that indicate the its widespread use and accessibility even to the rural population.

The proposed model was successfully implemented and tested. The developed model provided a technological solution that would monitor the water quality in real time. The convergence of the emerging technologies namely the smartphone and the wireless sensor technologies made it possible to develop the model. Inexpensive sensors were used to sense the different water parameters that are key for the fish survival in water.

7.2 Recommendations for further research

From the study of literature and interviewing of experts it emerged that there are numerous other variables that could be considered while taking care of the fish welfare. More sensor could be installed to scale up the model to a fully operational system. Powering the devices in remote areas and for longer periods of time can be considered for future implementations. Creating redundant devices can be implemented in case of failure of one of the sensors.

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Appendices

Appendix A: User Requirements Questionnaire

IoT-based Real Time Fish Pond Water Quality monitoring

The purpose of this questionnaires is to gather requirements for developing a Smartphone Based model for fish pond water quality monitoring. The information or data collected on this form shall strictly be used for academic purposes and shall be treated as private and confidential.

* Required

1. **For how long have you been fish farming?** *
   Mark only one oval.
   - less than 1 year
   - 1-5 years
   - more than 5 years

2. **To what extent do you agree that fish pond water quality monitoring is important?**
   Mark only one oval.
   - Strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly agree

3. **How often to you check water quality of the fish pond?**
   Mark only one oval.
   - many times a day
   - once a day
   - once a week
   - a number of days a month
   - Rarely

4. **The current Process of monitoring water quality provides instant status**
   Mark only one oval.
   - strongly disagree
   - Disagree
   - Neutral
   - Agree
   - strongly agree

Appendix B: Application Functionality and Usability Questionnaire

IoT-based Real Time Fish Pond Water Quality monitoring

The purpose of this questionnaires is to gather user opinion on the application usage. The information or data collected on this form shall strictly be used for academic purposes and shall be treated as private and confidential.

1. **The application's user interface is easy to Navigate**
   Mark only one oval.
   - strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

2. **The application displays real time status**
   Mark only one oval.
   - Strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly agree

3. **The application functions as desired**
   Mark only one oval.
   - strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

4. **I would use the application to monitor fish pond water quality**
   Mark only one oval.
   - strongly disagree
   - Disagree
   - Neutral
   - Agree
   - strongly agree

Appendix C Krejcie & Morgan Table

Table for Determining Sample Size from a Given Population

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size.
S is sample size.

Appendix D Ultra Sonic Sensor Specifications

Tech Support: services@elecfreaks.com

Ultrasonic Ranging Module HC - SR04

Product features:

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work:
(1) Using IO trigger for at least 10us high level signal,
(2) The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back.
(3) IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning.
Test distance = (high level time×velocity of sound (340M/S) / 2,

Wire connecting direct as following:

- 5V Supply
- Trigger Pulse Input
- Echo Pulse Output
- 0V Ground

Electric Parameter

Working Voltage	**DC 5 V**
Working Current	**15mA**
Working Frequency	**40Hz**
Max Range	**4m**
Min Range	**2cm**
MeasuringAngle	**15 degree**
Trigger Input Signal	**10uS TTL pulse**
Echo Output Signal	**Input TTL lever signal and the range in proportion**
Dimension	**45*20*15mm**

Appendix E Waterproof Temperature Sensor Sepcifications

HK Shan Hai Group Limited
Room 620 , Yutian building , songling road , Futian district , Shenzhen

DS18B20 Waterproof Temperature Sensor Cable

Product Description

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 (-67F to +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.

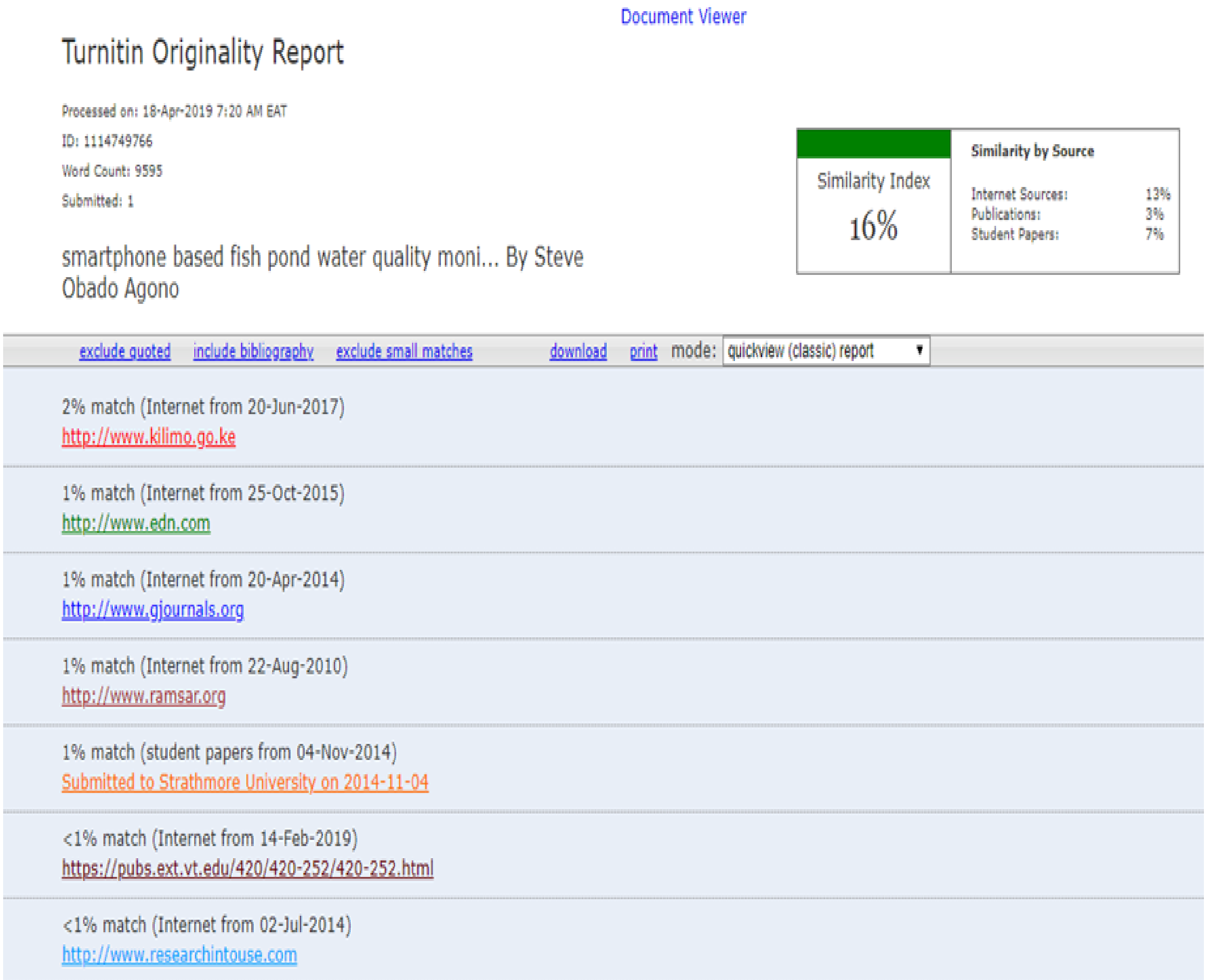
The datasheet of this DS18B20 Sensor can be found from:

https://dlnmh9ip6v2uc.cloudfront.net/datasheets/Sensors/Temp/DS18B20.pdf

Feature:

Power supply range:	3.0V to 5.5V
Operating temperature range:	-55°C to +125°C (-67F to +257F)
Storage temperature range:	-55°CC to +125°C (-67F to +257F)
Accuracy over the range of -10°C to +85°C:	±0.5°C
3-pin 2510 Female Header Housing	

Appendix F Originality Report



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