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Designing an IoT Based Smart Poultry Monitoring and Egg Production Prediction System (IoT-SPMEPPS)

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College of Science and Technology

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MSc in Internet of Things – Wireless Intelligent Sensors Networks

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Thesis' title

Designing an IoT Based Smart Poultry Monitoring and Egg Production Prediction System (IOT-SPMEPPS)

By

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

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In the College of Science and Technology

At the African Center of Excellence in IoT (ACEIoT)

Supervisor: **Dr. Louis SIBOMANA**

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BONIFIDE CERTIFICATE

This is to certify that the project work entitled "**Designing an IoT Based Smart Poultry Monitoring and Egg Production Prediction System**" is a record of the original work done by **Cecile MUSABYEMARIYA** registration number is **220002861**. It is in partial fulfillment of the requirement for the award of MSc with honors in Wireless Intelligent Sensors Networks at the African Center of Excellence in Internet of Things, (ACEIoT) College of Science and Technology in University of Rwanda during the academic year 2020 - 2021.

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DECLARATION

I declare that thesis entitled “**IoT Based Smart Poultry Monitoring and Egg Production Prediction System (IOT-SPMEPPS)**” is presented for the degree of Masters in Internet of Things-Wireless Intelligent Sensor Networking at African Center of Excellence in Internet of Things-University of Rwanda-College of Science and Technology is my original work. It has never been submitted in any University for the similar titles.

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ABSTRACT

Poultry farming plays a big role in reducing malnutrition problems due to the nourishment found in the chicken meat and eggs. Eggs and chickens are more consumable which makes poultry farming profitable to the poultry farmers. However, the parameters such as humidity, temperature, light intensity, gases such as ammonia and carbon dioxide, availability of food, and water have great effect on the quantity of eggs that hens lay in a given period. For example, when the laying hens don't have enough water, they become dehydrated and produce fewer eggs and they may even stop laying completely. Therefore, there is a need to monitor and control environmental parameters in poultry houses for making hens live well and more productive by laying as many as eggs they can. The purpose of this project is to help farmers to manage their farms efficiently, to facilitate poultry data record, to reduce manual labor, and to increase productivity. To reach this purpose, this project used Internet of Things (IoT) based in smart poultry monitoring and egg production prediction system. The prototype consists of sensors which collect poultry house related data and transfer those data to cloud and to web. For any required intervention from the farmer, the notifications will be sent through Short Messaging Service (SMS). This prototype would be used to control poultry operational.

Using IoT, the intelligent system was developed to capture data from sensors such as water level, gas, temperature, humidity, light intensity, egg counter, which are connected to the microcontroller equipped with Global System for Mobile communication (GSM) module for connecting system to internet through General Packet Radio Service (GPRS) and sending SMS messages. This is a smart solution that helps in keeping up the farm with the better conditions to the chickens and helps in prediction for eggs production based on current production and changes in parameters with minimal human effort. The data related to poultry farm with the state of environment is maintained at servers and analyzed for egg production in the future in the form of insights and can be retrieved as per need. For this project data related to how poultry farming operational are performed were collected using interview, observation, documentation and questionnaire methods.

Keywords: Poultry farming, Eggs prediction, IoT, Microcontroller unit, Sensors, Cloud computing, Wireless communication.

LIST OF ACRONYMS

AC: Alternative Current

ACEIoT: African Center of Excellence in Internet of Things

DRC: Democratic Republic of the Congo

FAO: Food and Agriculture Organization

GDP: Gross Domestic Product

GPS: Geographical Positioning System

GSM: Global System for Mobile communication

GPRS: General Packet Radio Services

IoT: Internet of Things

LCD: Liquid Crystal Display

LED: Light Emitting Diode

ML: Machine Learning

PIR: Passive infrared

SMS: Short message service

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CHAPTER I: GENERAL INTRODUCTION

1.0 Introduction

Nowadays, Internet of things (IoT) and cloud computing technologies are evolving at a very high speed, and these are being used to move from manual system which is not effective to automated system. IoT has strong impact to the real-life domains like agriculture, healthcare, transportation and other areas that can be improved effectively with the use of this smart technology [1].

The use of IoT facilitates the operation of the domains in which it is applied, it is also used to improve and or enhance their efficiency and effectiveness. Many disciplines including agriculture are developing at astonishing speed by integrating new technologies in their applications [2].

Some farmers from poultry industry in Rwanda are still using manual systems, while others are trying to modernize their farms. IoT based Smart Poultry Monitoring and Egg Production Prediction System (IoT-SPMEPPS) comes in to reinforce poultry industry. This system enables poultry farmers to automate the operations, keep all data in a secure way and improve the quality and quantity of meat and eggs. This system also reinforces poultry farming as a source of reliable food and high rate of income by improving the existing system with IoT technology. The system also enables farmers for monitoring and evaluation of the effectiveness of their business as well as planning according to the analysis of the data by using Machine Learning (ML).

1.1 Background

Poultry farming is one of livestock raising in which the family-based birds like ducks, chickens, geese, and turkeys are taken reared in order to produce meat or eggs for food and earning money. The big part of poultry in Rwanda is composed by chickens which are in two categories; chickens for meat also known as broilers and chicken for eggs also known as layers. IoT Based Smart Poultry Monitoring and Egg Production Prediction system focused on chickens for eggs. However, these hens can be consumed when they have grown old and have stopped laying eggs. Due to insufficiency of land in Rwanda originated from the high increase in number of populations, the poultry farming is easily practiced since it doesn't require a big land to build houses or a high startup capital compared to other businesses. Also there is an increase in demand of poultry meat and eggs. Thus; many Rwandans chose to be engaged in poultry farming [2].

Poultry farming has the great impact on the human living style [3] and it is growing fast together with the demand for animal protein. In Rwanda, poultry is frequently found in rural areas. About 69% of all poultry farmers in 2017 was rearing one to two chickens [4]. In few years back the Government of Rwanda acknowledged the importance of poultry to the country in fighting malnutrition especially in children bellow five years old, as it is also fought an unemployment in youths due to high income got from commercialized poultry farming [5]. Rwanda livestock master plan published in 2017 [4] showed that poultry had to cover market in the next 5 years. The goal was to make the country's poultry industry from dominantly subsistence-based to knowledge-intensive and market-oriented. From that direction, the government enhanced the productivity of poultry industry by supporting the farmers through aids and loans aiming at improving the poultry farming so that poultry industry can produce more foods for better life of poultry owners and improved health for Rwandan people.

Though many entrepreneurs engaged in poultry farming, there are still challenges that are weakening this industry like diseases, poor management and predation as highlighted by Mazimpaka E. et Al [6] in their research titled "Assessment of Poultry Production System in Rwanda, A Case Study in Nyagatare District" and they advised the participants in poultry sector to strengthen the way of controlling diseases in a poultry farm by modernizing the poultry farming in order to be able to take more attention on living conditions of chickens in a poultry house. This would contribute to the improvement of poultry sector for a better production of eggs and in order meet the market demand at low cost [6]. In general, the management of environmental conditions and balanced diet is very important task but which is difficult to accomplish with manual processes.

1.2. Problem statement

Among the investment opportunities exist in Rwanda, Poultry farming is the fastest growing livestock sector which started quiet recent and it is a fast and high profitable with around 50% to 55% profit from eggs [7]. Farmers invest in poultry by spending time and money to pay for building house or cages, drinkers, feeders, day old chicks and the feed to raise the chickens. Poultry farmers get their money back for hens when these hens start laying eggs. Despite its benefit, poultry farming like other agricultural sub-sectors has been affected by high increase in population. As the population increases, the land for farming reduces and there is an increase in the demand for food. The farmers have to incorporate new technologies in order to face the challenges carried out by the increase in population.

The global research carried out in April 2019 [8] has shown that the consumption of poultry meat and eggs increases the quality of food in general because eggs are good source of vitamins and protein. Food and Agriculture Organization (FAO) advises the world to have poultry meat and eggs in high availability and at low cost especially in developing countries from where there is a deficit in accessing nutritive food. Chicken and eggs are a perfect food for people with malnutrition, pregnant woman, and breastfeeding as well as for old people and young children [8].

The environment conditions such as temperature and humidity have the great effects on chickens laying and health. High concentration in gases like ammonia and carbon dioxide in poultry house decreases the growth of the chickens and thus their eggs production is reduced [9]. Improper management of living conditions in poultry farm leads to failure in maintaining healthy and productive hens. Processes that are needed to be managed include controlling quality and quantity of food, quantity of water, and environment parameters such as humidity and temperature, gases and sunshine hours.

This thesis focuses on designing and prototyping an IoT based smart poultry monitoring and eggs production prediction system, to automate, control and manage poultry farming remotely. This system will keep poultry farm more stable and comfortable to the chickens as well as to fix the factors that can make hens to lay fewer eggs or even to stop laying completely in order to gain more eggs and reduce risk of chicken's health and that of people consuming chicken meat and eggs. In addition, this system intends to reduce labor effort that people responsible for chickens use while visiting the chickens' house all times. The issue of fire security for the chickens is monitored using gas sensor.

The developed system will be connected to the Internet and the data from the farm will be stored in a database on cloud server and on farmers' website database. Based on the data collected by sensors deployed in a farm, the farmer can monitor the farm from anywhere and being notified through SMS and alarm. When any problem is encountered in a farm the farmer can intervene when necessary.

1.3 Purpose of the study

Due to the importance of chicken's meat and eggs for human healthy, the poultry farming the simplest livestock should be promoted in Rwanda. The design and implementation of IoT based smart poultry monitoring and egg production prediction system has been selected in order to improve the nutrient in Rwandan citizens and for help the Country in reducing the number of unemployed among people by applying this technology in the poultry farming.

1.4 Aims and objectives

The aim of this project is to develop an IoT prototype for smart poultry farming monitoring in order to improve the poultry operational efficiency at lower cost and make the poultry farming more profitable as well as increasing eggs production.

1.4.1. Specific objectives

- Review existing poultry monitoring system for their weakness and limitations
- Propose a low-cost prototype for regulating the temperature, humidity, sunshine hours, ammonia and carbon dioxide more adequate to the chickens.

- Propose an IoT prototype for Real time automatic water and food supply and control.
- Propose the egg production prediction algorithm based on the data collected from poultry farm.

1.5 Scope of the study

Different researchers and developers have worked on how to develop the poultry industry, but the systems designed are not easy to be adopted in developing country like Rwanda because they require high amount of money. The system developed in this project involves poultry farmers in Rwanda and it is simple in terms of money and its implementation doesn't require high knowledge.

1.6 Hypothesis

The IoT based smart poultry monitoring and production prediction system has a potential impact on chicken's health. This project focuses on automating poultry farming processes, monitoring the farm remotely and analysis of data captured from poultry farm in order to predict and plan for the future egg production. The application of IoT in poultry farming is very helpful in production of quality meat and eggs and in high quantity.

1.7 Significance of the study

The world bank report [10] stated that the high rate of Rwandan people depends on the agriculture for their livelihood but this sector is struggling due to land scarce caused by the high population growth. Population increases but the land does not. In general, poultry farming regardless broilers or layers doesn't require a big land which answers to the problem of land scarce. Therefore, poultry farming is the suitable job in this generation where we need to produce more from low space. The project aims at improving the poultry industry. When this project is implemented, it will help farmers to monitor and control their farm from anywhere anytime, for the sake of getting high production from their chickens. In addition, problems related to the improper management of poultry farm like diseases in chickens, not growing, low productivity of eggs will be addressed.

1.8 Motivation

Chickens are the best source of eggs, meat and fertilizer. Young business starters choose rearing the chickens because they don't require high investment compared to rearing other livestock. In addition, the production can be given and increased within a short period of time. In the years of 2010 and back, poultry farming was not considered a business that can generate money. Poultry was done as a subsistence job where a family used to have 1 to 5 chickens for home consumption. Currently, there are many entrepreneurs engaged in poultry farming as a business. The engagement in poultry farming was strengthened by the change in Rwandan mindset of whereby people were convinced on the importance of taking a balanced diet containing nutrients. This awareness increased chickens' eggs and meat demand.

1.9 Organization of the work

This thesis is divided into five (5) chapters. Chapter I emphasizes on general introduction, background of the problem, problem statement, aims and specific objectives, scope of the study, hypothesis, significance of the study and organization of the work. Chapter II provides literature review. Chapter III highlights the research methodology and system design. Chapter IV represents the implementation of the IoT Based smart poultry monitoring and egg production prediction system and discussion of the results and Chapter V which is about the conclusion and recommendations.

CHAPTER II: LITERATURE REVIEW

2.0 Introduction

This chapter explains poultry categories, poultry management and shows the ideas from related works.

2.1 Categories of poultry

Poultry sector is divided into two systems which are village or traditional poultry and commercial poultry. Village poultry occupies 69% of all poultry farmers in Rwanda [4].

Figure 1. Photo for Village poultry

Figure 2. Commercial poultry farming

Poultry meat and eggs have the big importance in human's diet. In order to produce many eggs, the farmers need to move from traditional to commercial Poultry [4]. The differences between traditional and commercial poultry as indicated by George D. Wesoloski [11].

Tradition system vs commercial system

Constraints	Traditional system	Commercial system
Areas	Largely in rural areas	Largely in urban areas

Size	flock size is usually between 2 and 20 birds per household	larger flock sizes
Purpose	Eggs and meat consumption by farmers themselves or their neighbors	sales of chicken meat and eggs
Method	Free-range	Intensive poultry Houses or cages
Time	Many years ago	Initial stage
Feeding system	Scavenging	(semi)automatic feeding systems
Production	Low	High
Risk	High	Low
Source of chicks	poultry farmers initially buy the birds from neighbours or village markets. After that, replacement of flock almost exclusively happens with their own birds8	Hatchery

Table 1. Traditional vs commercial system

2.2 Poultry management

For fresh eggs and meat, farmers need to properly manage their farms to ensure constant health conditions of their chickens. When a poultry farm is not well managed it can cause the death of chickens and not well growth thus the low productivity and less income. According to Dr. Karri Rama Rao [12] India is the 3rd largest producer of eggs and 5th rank meat production in the world due to the intensive systems which help the farmers to properly manage the poultry farm. The main things to think about before starting poultry farming of laying hens are housing system, food and egg production.

2.2.1 Housing

For proper growth and quality eggs and meat production, husbandry must ensure that the chickens have the adequate amount of space and are getting fresh air, sufficient light and sunrise in their house. There are two main housing system for chickens that are houses and cages.

Table 2. Chickens reared in house

When building chickens house or cages, the husbandry must obey these measurements; $1m^2$ for 20 baby chicks of 1 to 4 weeks, $1m^2$ for 10 teenage chickens of 1 to 5months and $1m^2$ for 5 laying hens [13].

It is better to keep the chickens of the same age in the same house or cage [14]. The baby chicks, teenage chickens and laying hens live in different houses or cages because their managements are different. For example, baby chicks need warm environment and starter-grower food [15]. Laying hens need the nesting boxes and diet different to that of baby chicks and teenage chickens. Therefore, chickens are grouped in broods of the same age each.

2.2.2 Feeding

The quality of food and water for chickens plays a big role in chicken's growth and eggs production [16]. In order to get a high reasonable income from poultry farming, the husbandry must feed his/her chickens with a balanced diet according to their stages of development as follows [17]: 15g of food and 40 to 50 ml of water are given to a baby chick of 1 day to 3 weeks; 25g of food and 50 to 60 ml of water are given to a baby chick of 3 to 5 weeks; 35g of food and 60 to 70 ml of water are given to a baby chick of 5 to 8 weeks; 50g of food and 70 to 80 ml of water are given to a baby chick of 8 to 10 weeks; 60g of food and 80 to 100 ml of water are given to a baby chick of 10 to 20 weeks; 100g of food and 100 to 120 ml of water are given to a teenage chicken of 20 to 21 weeks; 120g of food and 140 to 160 ml of water are given to a teenage chicken of 22 weeks; and 130g of food and 180 to 200 ml of water are given to a laying hen. The balanced food is composed by different ingredients [18] such as maize grain, soybean grain, premix vitamin, sunflower, salt, shells, bones, etc. Some ingredients used to prepare balanced diet for laying chickens are shown in figure 2.5.

Figure 3. Chicken food ingredients

2.2.3 Production

Rwanda produces 30,000 tons of eggs and 2,144 tons of chicken meat every year from indigenous chicken [19] but it is not enough yet because Rwandan poultry farmers don't produce for only Rwandan market, they also export to nearest countries particularly RDC. The new times in its news titled "Rwanda's poultry industry on the rise" published on 5th October 2019 [20], it announced that for layers, Rwanda had 15 large commercial poultry farms and 108 medium poultry farms. A large poultry farm contains between 20000 and 100000 layers while the medium farm contains between 5000 and 20000 layers. The country had also over 222 small commercial poultry farms containing 1000 to 5000 layers. For broilers, the country had 10 large farms, 25medium farms and 20 small farms.

2.2.4 Poultry farming challenges

The challenges that poultry farming is facing include expensive chicken feed, diseases, management, availability of medicine, inadequate poultry house. Figure 2.7 shows the inadequate drinker, feeders in inadequate poultry house identified in figure 2.6.

Figure 4. Inadequate poultry house

All these challenges lead to low productivity and high mortality in poultry farms. In order to overcome these challenges, poultry farmers need to feed their hens with quality feeds, ensure hygiene and keep their hens vaccinated. [21]

2.3 Related work

Different researchers proposed systems to improve the way of doing poultry farming. Archana MP et al [22] proposed a system to monitor and control the chicken's physical surroundings parameters through the internet. This system was designed and implemented using temperature, gas and light intensity sensors, food valve and GSM which are integrated with microcontroller. In this model the physical conditions are regulated automatically while feeding is triggered by a farmer remotely through mobile phone. The limitation in this system is that water was not considered being more important to the chicken.

Also no camera installed to monitor poultry farm remotely, and there is no automatic way of collecting and counting eggs.Gbadamosi A [23] proposed a system that monitors the temperature and humidity and every 5 seconds the information is sent to the cloud. The drawback of this system is that after monitoring the temperature and humidity depending on the result, there is no automatic control on regulating temperature and humidity levels.D. Mahfujul Islam et. Al [24] proposed a system in which IoT devices are incorporated to operate according to the parameters from the farm. Door and gas sensors are used for security purpose from thief and fire respectively environmental parameters are collected also and stored to ThingSpeak. The limitation is that after collecting data and send them to ThingSpeak, the system is not automated to regulate environment parameters and feeding systems.

Eric Hitimana et. Al [9] proposed as system to monitor and control poultry farm using IoT Techniques. Wireless sensors are integrated with the microcontroller; ventilations and heater work automatically with no human effort; all captured data are sent to the cloud and the farmer is able to get real time information of his farm. The limitation is that there is no automatic way of collecting and counting eggs. And after analysis there is no prediction done. Muhammad F. H. H. et. al [3] developed a prototype using IoT and wireless sensor network to capture environmental parameters and automate processes when data values exceed the limits. The limitation is that there is no way of counting eggs and no prediction done. From view of previous researchers, the existing system tends to facilitate poultry operational but still there is gap about recording egg production and prediction of future egg production based on the current environmental parameters and eggs produced. This thesis aims at designing IoT based prototype for recording eggs laid and predict future egg production based on current data captured from poultry house.

CHAPTER III: RESEARCH METHODOLOGY

3.0 Research design

Methodology is considered to be the strategy of the research including studying the existing system in order to develop the new system that meets the objectives of the research [25]. For this project data related to how poultry farming operational are performed were collected using interview, observation, documentation and questionnaire methods [26] addressed to the poultry farmers to explain how poultry farming is being done. After gaining the data required, we identified the requirements for prototyping IoT based smart poultry monitoring and egg production prediction system.

3.1 Target population

Target population is a term used to mean the group of elements that you want to know more about [27]. In this thesis, the target population of the study consists of the poultry farmers who rear laying hens from 100 hens and above from four provinces of Rwanda.

3.2 Sample population

Sampling is the approach of selecting subgroup of whole population and estimate properties of the entire population [28]. In this thesis, clustering sampling technique was used to get a sample. The sample was taken in four provinces. It means, one district per province, ten farmers per each district except Muhanga that presents twenty farmers because it is where we found many poultry farmers. Then the total sample comprises fifty farmers.

3.3 Data collection

3.3.1 Observation

Observation is the primary data collection method by which the researcher gets knowledge about the phenomenon through making observation when that phenomenon is occurring [29]. In this research, six (6) farms in Mushishiro sector within Muhanga District, Southern province were visited to observe how poultry farmers operate on field, looking at problems shown and to identify the technique to be used for solving the identified problems.

3.3.2 Interview

Interview data collection method, involves the researcher and the interviewee in conversation through open ended questions. The interview can be conducted face to face when possible or through online meeting or telephone [30] [31]. In this research, both formal and informal interview were conducted with three poultry farmers from Muhanga district through face to face, three from Karongi district, three from Rwamagana district and three from Rulindo district through telephone were interviewed and sampled conveniently.

3.3.3 Documentation

Using documents and record, the researcher can obtain huge amount of data using existing data for study [26]. In this research some information from other researches were considered such as the information about ambient temperature and humidity for chickens.

3.3.4 Questionnaire

A questionnaire is a paper containing a group of questions including both open and close-ended questions. The questionnaire can be hard copy or be in a form to be filled online. In this thesis, the printed questionnaire was prepared and given to 30 farmers located in different district including Muhanga, Rulindo, Rwamagana and Karongi district who are not able to access online questionnaire. Also online questionnaire through forms was given to 20 farmers located in the district listed above who have the ability to access that type of questionnaire.

3.4 System design

3.4.1 Equipment used

Microcontroller, sensors and actuators interconnected are used to monitor and control poultry house remotely and forecast based on data generated from the poultry farm. Sensors are used to measure the physical quantity and to give information to the system about environment, actuators convert the electrical signals into the physical events and accepts command to perform a function by taking the input from the system and gives output to the environment in form of event [32] and the microcontroller uses its Input/Output peripherals to communicate and approve the appropriate action in poultry house [33]. Data sensed are sent to the cloud for further analytics and storage for future use. The figure indicates how the system is designed.

3.4.2 System architecture

In this thesis, the system design describes the proposed system architecture, the technologies and the interconnectivity for integrating all tools including hardware and software requirements for IoT based smart poultry monitoring and egg production prediction system. Initially, the environmental parameters in a farm are captured using temperature and humidity sensor, gas sensor, light intensity sensor. Also, the status of the feeder and drinker is identified through water sensor for water delivery and regulated time for feeder. And the PIR sensor is there to count the number of eggs. All sensors are integrated to microcontroller which help in sending data to ThingSpeak. Once the temperature and gases pass the upper limit, the farmer notified for the intervention in a poultry farm and the status of the farm is provided through SMS. The figure demonstrate how the hardware and software tools are interconnected including sensors, communication media, cloud and data visualization through SMS on mobile phone.

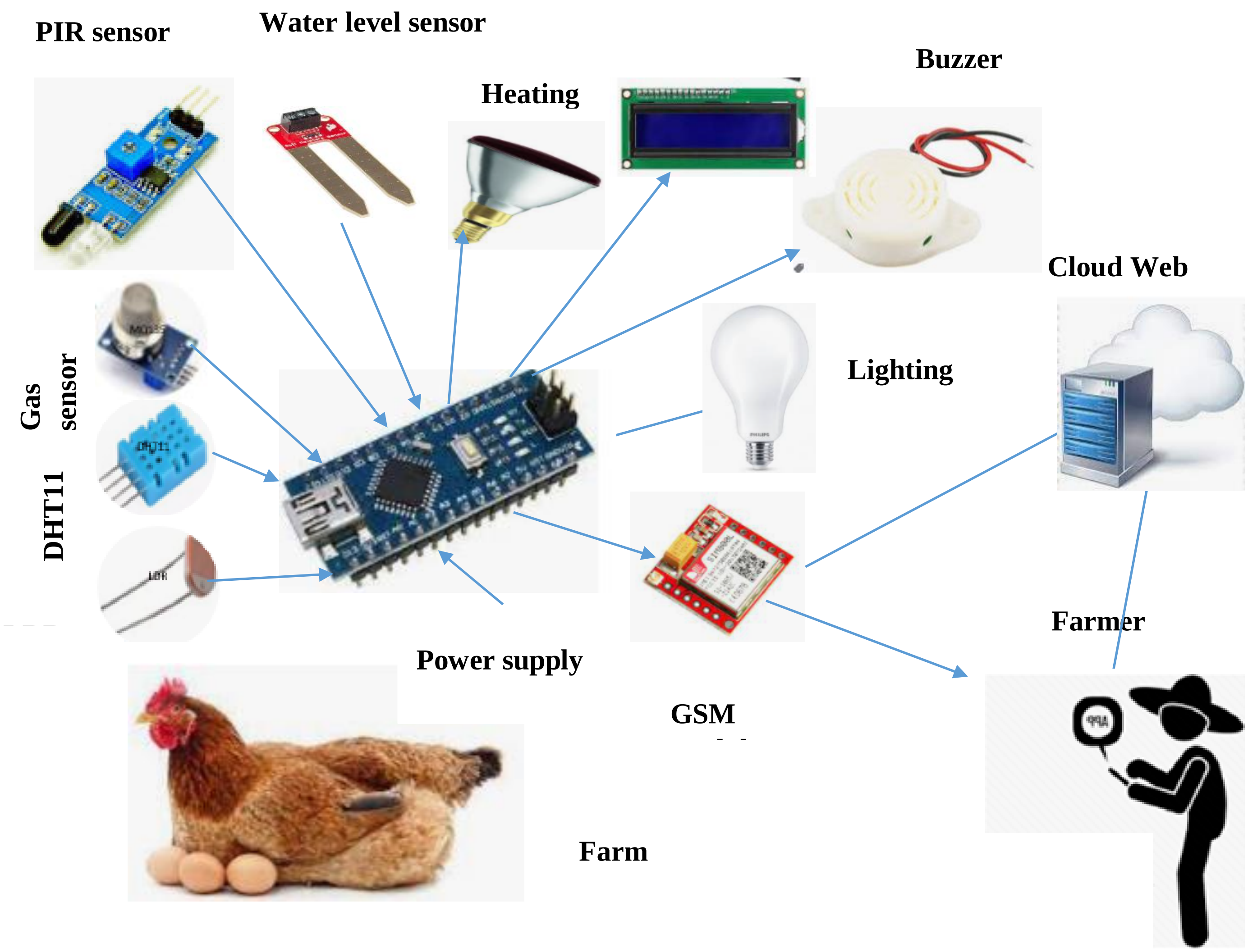


Figure 5. System design

`3.5 Hardware requirements

The system is composed by the wireless sensors to capture environmental parameters and counting eggs integrated with the microcontroller and the actuators to control poultry operations. The table 3.1 describes all hardware used in the system.

No	Name	Uses
1	**DHT11**	It was used to measure the temperature and humidity
2	**Bulb**	It was used to illuminate the space
3	**LDR**	It was used to measure the light intensity
4	**GSM**	It was used to communicate the farmer with the SMS and to provide WI-FI

5	**Microcontroller**	It was used to take data from sensors process them and send them to the server
6	**PIR**	It was used to count eggs
7	**Buzzer**	It was used to alert the farmer about the increase in gases or when there is no water in a drinker.
8	**Heating bulb**	It was used to heat the poultry house when the temperature is very low.
9	**MQ135 sensor:**	This sensor was used to capture Ammonia (NH_3) and CO_2 gases in the poultry house.
10	**Cooling fan**	It was used to blow out humidity and gases from poultry house.
11	**LCD display**	Liquid Crystal Display was used to display the environmental parameters in poultry house. stands for Liquid Crystal Display.
12	**MQ135 sensor**	This sensor was used to capture Ammonia (NH_3) and CO_2 gases in the poultry house.
13	**Water level sensor**	It was used to check the upper and lower limit of water in the water container or drinker
14	**Servomotor**	It was used for opening and closing feeder when it is the time for feeding
15	**Pump**	It was used for watering the chickens on the condition from water level sensor

Table 3. Hardware descriptions

3.6 Software requirements

In this section, the software used in this project were described.

3.6.1 ThingSpeak

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize and analyze live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by your devices to ThingSpeak. ThingSpeak is often used for prototyping and proof of concept IoT systems that require analytics. Temperature and humidity sensor, gas sensor, light intensity sensor and PIR sensors connected to GSM to send data from poultry farm to ThingSpeak using API key and send SMS notification on mobile phone of the farmer.

3.6.2 Arduino IDE

Arduino IDE used to write codes and helps to upload them to the Arduino board.

3.6.3 Anaconda

Anaconda was used as distribution of different software like Python, Jupyter, Pandas for machine learning.

3.6.4 Xampp

Xampp was used as server to create database for storing data

3.6.5 PHP

PHP was used as scripting language to connect database with the interface

3.6.6 CSS

CSS was used for layout and style of interface

3.6.7 HTML

HTML was used for creating web pages

3.6.8 Javascript

JavaScript was used for interacting users and webpages

3.6.9 Orange

Orange app was used for prediction

3.6.10 Thingspeak

Thingspeak is used as an IoT platform used to put data together at cloud and analyze them.

3.7Algorithm

Algorithm is a sequence of instructions involved in solving a problem. To express the algorithm, the natural language, pseudocode and flowchart can be used. In this project, the flowchart was used to describe the algorithm of the system.

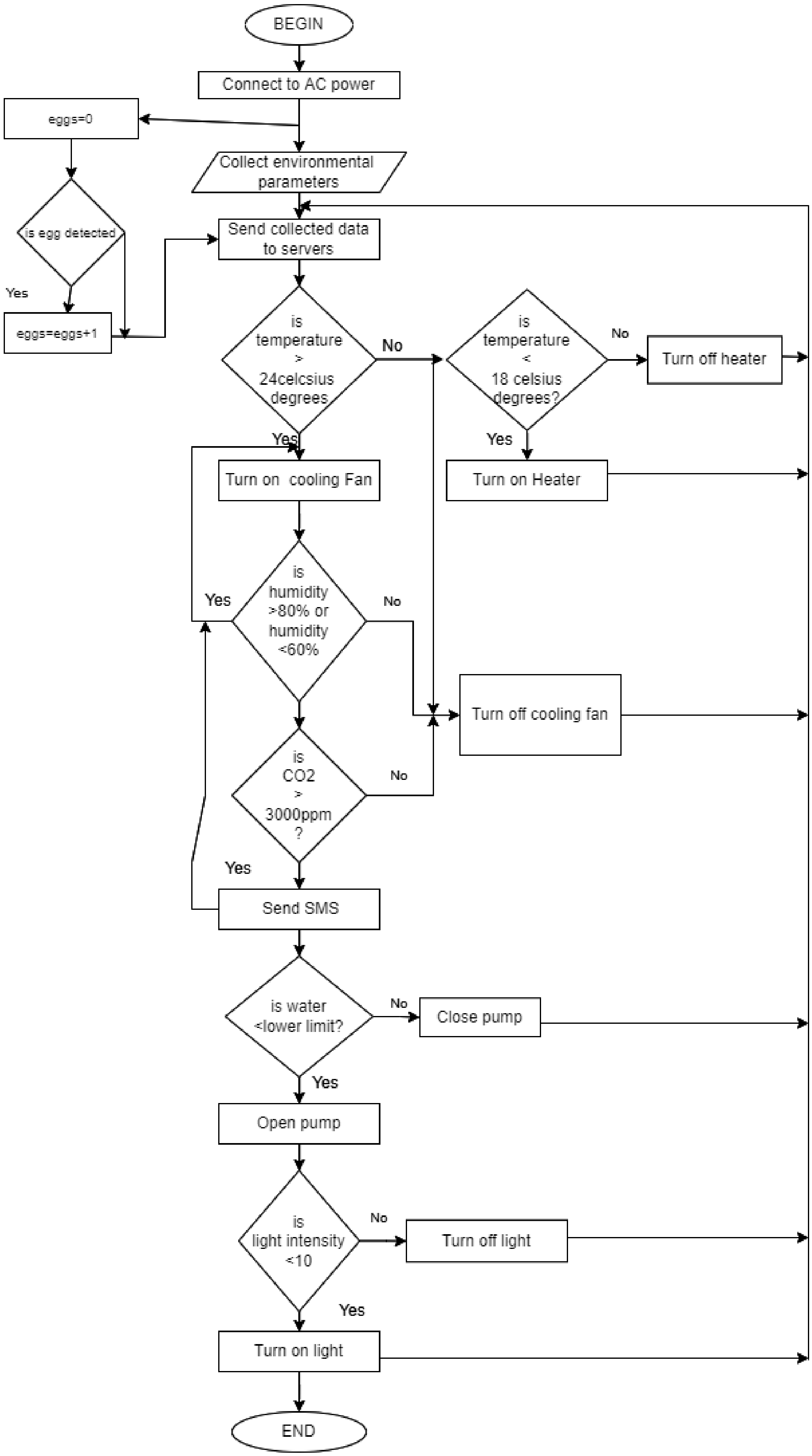


Figure 6. Algorithm for the system

Table summarizes the best conditions for laying hens and it explains how they can be maintained with the use of the prototyped system.

No	Parameters	Range	Action to be taken automatically	comments
1	Temperature	Ambient temperature for hens ranges between 18 and 24C	• When the temperature is above 24C, the cooling fan is turned ON • When the temperature is below 18C, the Heater is turned ON • When the temperature is Above 30, both buzzer and Heater bulb are turned ON	When the farmer hears the buzzer alert, the farmer knows that there is an unusual bad thing that happens in poultry house and goes there to intervene.
2	Humidity	Relative humidity ranges from 60% to 80%	• When the humidity is above 80% or humidity is below 60%, the cooling fan is turned ON	
3	Light intensity	14 to 16 hours of light everyday	When it is dark in a poultry house, the light bulb is turned ON	Don't provide artificial light for hens under the age of 16 weeks because to expose young chicken to too much light very soon can cause that chicken to develop eggs before her body is ready to support egg-laying.
4	CO_2	CO_2 should be kept below 3000ppm	When the CO_2 goes above 3000ppm, the fan is turned ON	High concentration of CO_2 and NH_3 are harmful to chickens.
5	NH_3	Ammonia gas should be kept below 20ppm	When Ammonia gas level is above 20ppm, the buzzer sounds and SMS is sent to the farmer	High concentrations of Ammonia may cause respiratory diseases. The farmer visits the poultry house to check the causes of excess gas and intervene in its reduction
6	Food	One laying hen needs 100 to 150g of feed per day.	In this prototype, the servomotor controlled by Arduino, opens food container every 5min	This automatic feeding system helps the farmer to save food and reduce labor cost
7	Water	A laying hen consumes water that is three	Every time when the drinker is empty the pump fetches water to fill the drinker	Water is the most important nutrition for laying hens. Water is essential for digestion, egg

		times the food it consumes per day.		production, and regulating body heat.
8	Space	One hen requires 2.5 to 3 square feet floor space in order to be comfortable	-	Ideal space for laying hens makes hens to be comfortable and laying eggs happily.

Table 4. The best conditions for laying hens [35]

CHAPTER IV: IMPLEMENTATION AND DISCUSSION OF RESULTS

4.1 Prototyping

This chapter represents prototype of the system implementation and discuss the results of IoT based smart poultry monitoring and egg production prediction system. This system automates the poultry operations by detecting environmental parameters, water level, light intensity, presence of ammonia gas and check whether it is the time to feed the chickens by using the appropriate sensors. Data captured are sent to the server for further processing and decision taking like turning on LED, cooling fan, heater or opening pump for water feeding. The figure shows the system prototype connectivity deployed in a farm.

Figure 7. Prototype of the system

The prototyped system is deployed in chicken house in order to monitor and control the environmental parameters. The Figure 4.2 below indicates the hardware connectivity and prototype components which composed smart poultry monitoring system. All sensors, actuators, feeder, drinker and communication module are connected together on Arduino that works as a gateway to send data captured from hens' house to cloud and farmers' website and to control actions to actuators.

4.2 Results

All sensors are connected to microcontroller which is connected ThingSpeak. The data captured are sent to thing speak which sends them to the web application through API. The developed prototype has been tested for different poultry farms which are located in Mushishiro sector, Muhanga District, Southern province and the data are captured and sent to cloud and mysql database from where the farmer is able to visualize data through Thingspeak platform, web interface and through notification via SMS. The visualization of data about environmental status in poultry farming can be done in four different ways: through ThingSpeak, through LCD, through Mysql Database and through SMS

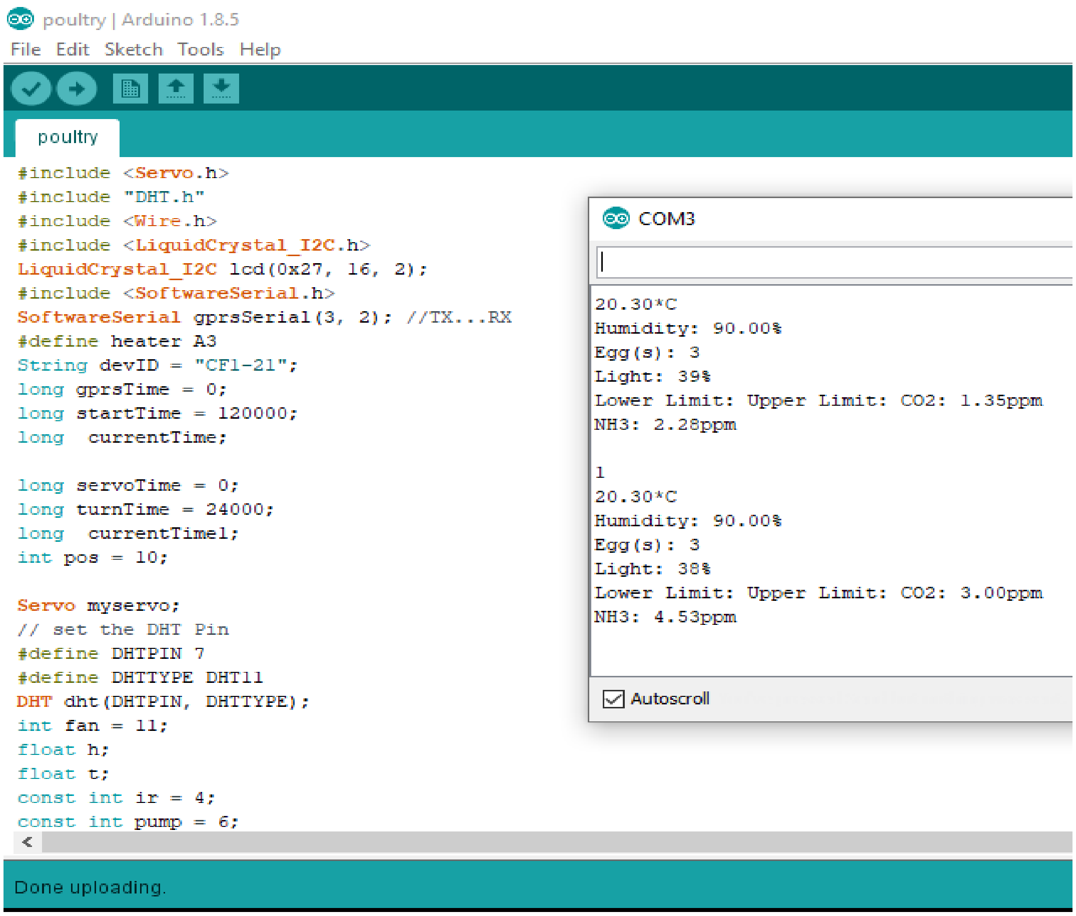


Figure 8. Arduino code and serial monitor of IoTSPMEPPS

Arduino code is written and uploaded to microcontroller, microcontroller executes the data and display on screen through serial monitor.

4.2.1. Visualization of data

To visualize the data from ThingSpeak, the farmer should provide the credentials including email and password in order to access ThingSpeak account.

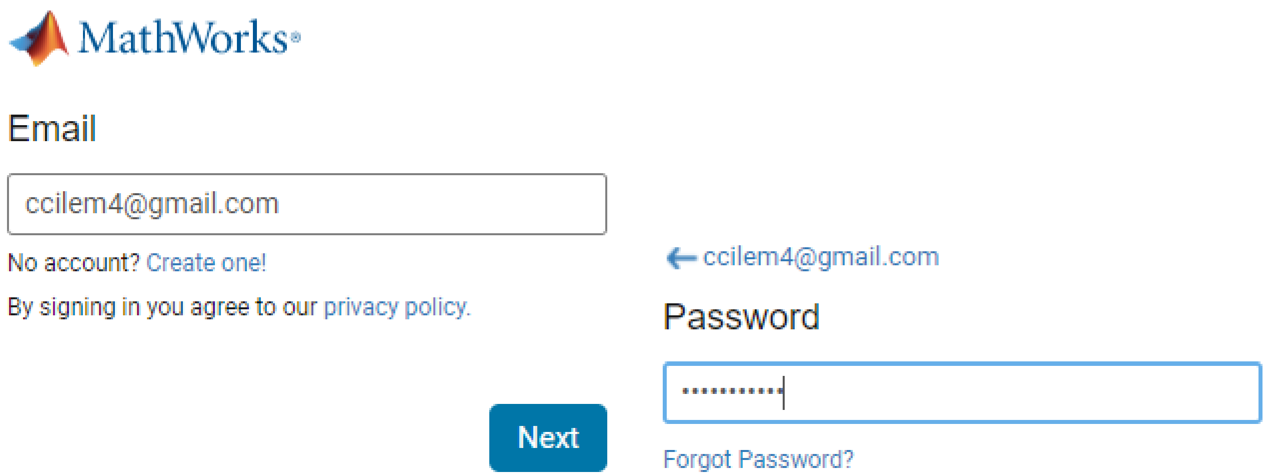


Figure 9. Farmer's Email example

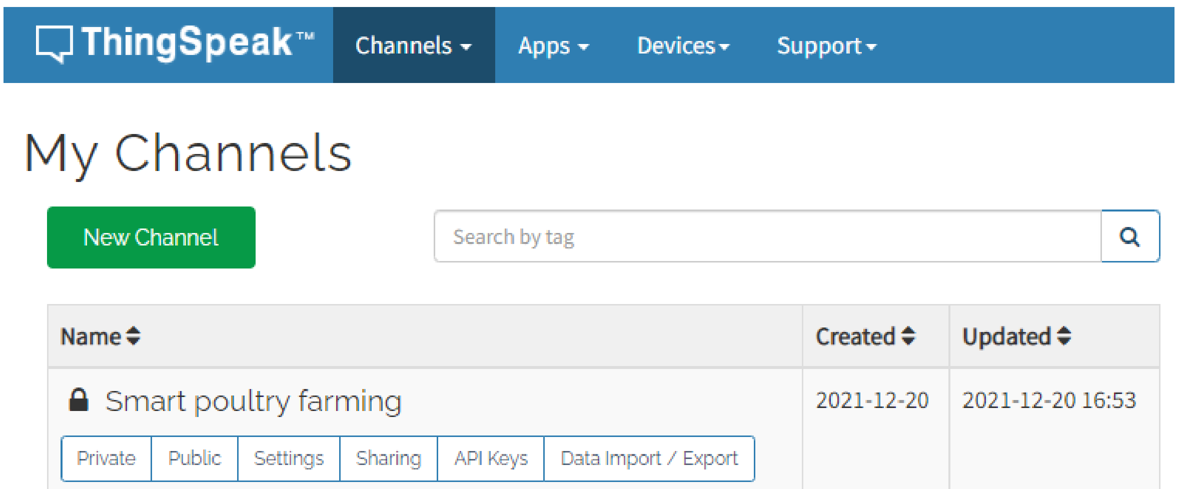


Figure 10. ThingSpeak channel for storing, analyzing and visualizing data

This sample data was taken on 2nd October 2021 except variation of eggs produced the chart taken from December 2021 to March 2022.

Figure 11. Smart poultry farming, temperature details

Figure 12. Smart poultry farming, humidity details

Figure 13. Smart poultry farming, food level

Figure 14. Smart poultry farming, water level

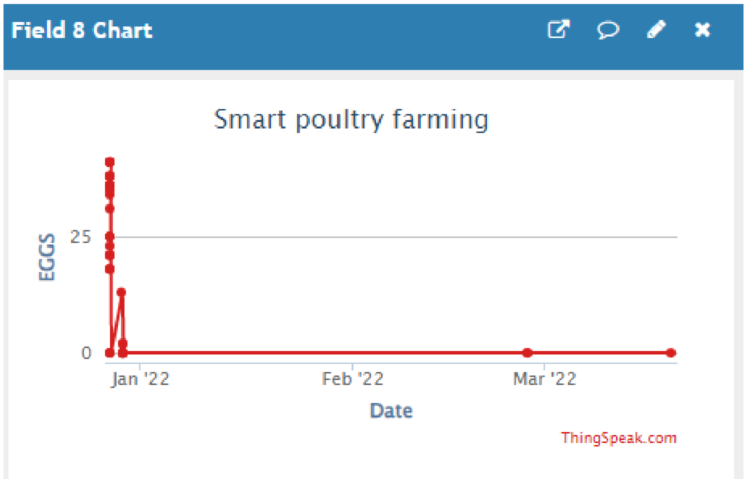


Figure 15. Smart poultry farming, eggs level

Through ThingSpeak also the data can be visualized via CSV file. The figure shows the sample of CSV file exported from ThingSpeak.

	A	B	C	D	E	F	G	H	I	J
1	created_at	entry_id	field1	field2	field3	field4	field5	field6	field7	field8
2	2021-12-24T13:33:15+00:00	1	29.8	49	71	136.49	154.41	600g	1L	13
3	2021-12-24T13:39:31+00:00	2	29.4	49	93	4.27	2.8	600g	1L	13
4	2021-12-24T13:41:31+00:00	3	29.1	50	86	3.95	2.56	600g	1L	13
5	2021-12-24T13:51:28+00:00	4	28.3	53	93	3.74	2.41	600g	1L	13
6	2021-12-24T13:53:28+00:00	5	27.7	55	90	4.49	2.96	600g	1L	13
7	2021-12-24T13:55:29+00:00	6	27.9	51	87	0.19	0.08	600g	1L	13
8	2021-12-24T14:15:38+00:00	7	31.5	46	78	1071.39	1675.96	600g	1L	13
9	2021-12-24T14:22:26+00:00	8	28.3	55	79	1.11	0.59	600g	1L	13
10	2021-12-24T14:24:27+00:00	9	28.1	57	97	0.79	0.4	600g	1L	13

Table 5. CSV file exported from ThingSpeak.

4.2.2 SMS alert

Arduino board equipped with GSM shield sends SMS message to a configured mobile phone number. The figure shows the messages about poultry farm status sent from Arduino to a provided mobile phone number.

Figure 16. SMS messages sent the farmer

This prototype sends alerts to the farmers through SMS on mobile phone and buzzer sound when there is a high concentration in carbon dioxide and ammonia gases and when there is an increase of temperature above 30 degrees Celsius.

4.2.3 Web interface for farmer

Once a farmer needs to monitor his/her farm through web application, the farmer enters the credentials of email and password on the login interface when the credentials match with which stored in database the farmer will get access and continue with recording farmers' information or visualizing data about poultry house status in terms of environmental parameters. The figure 4.17 shows the login interface for farmer.

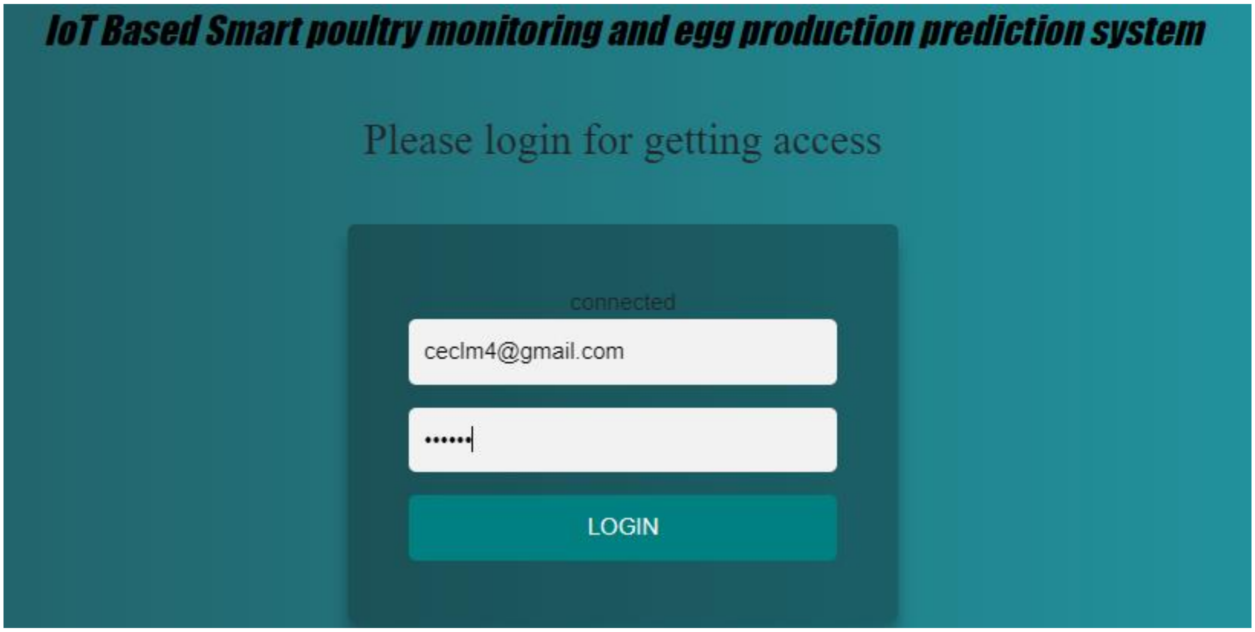


Figure 17. Web interface for farmer

After login, the farmer will get the information.

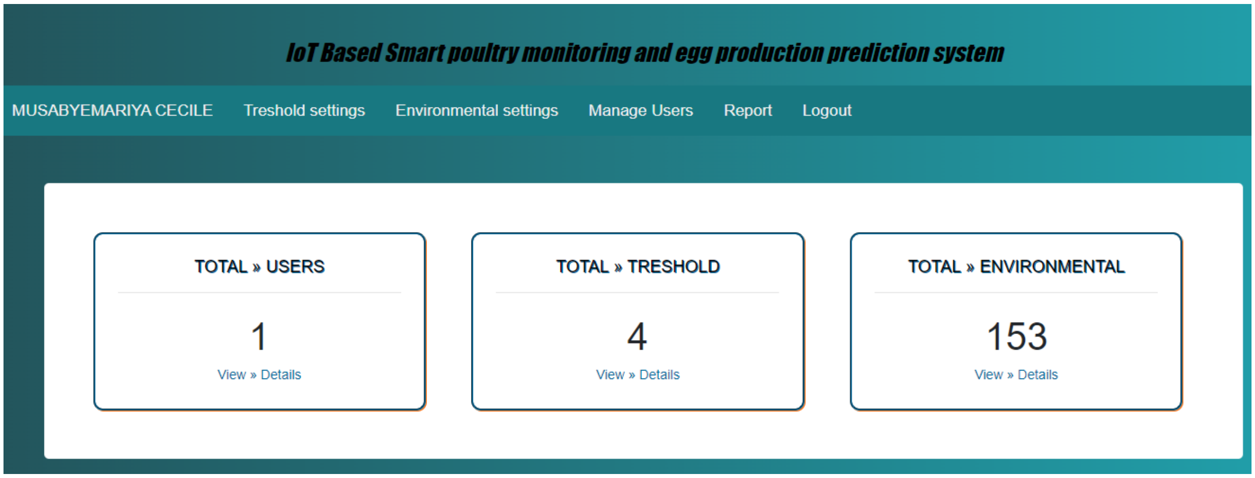
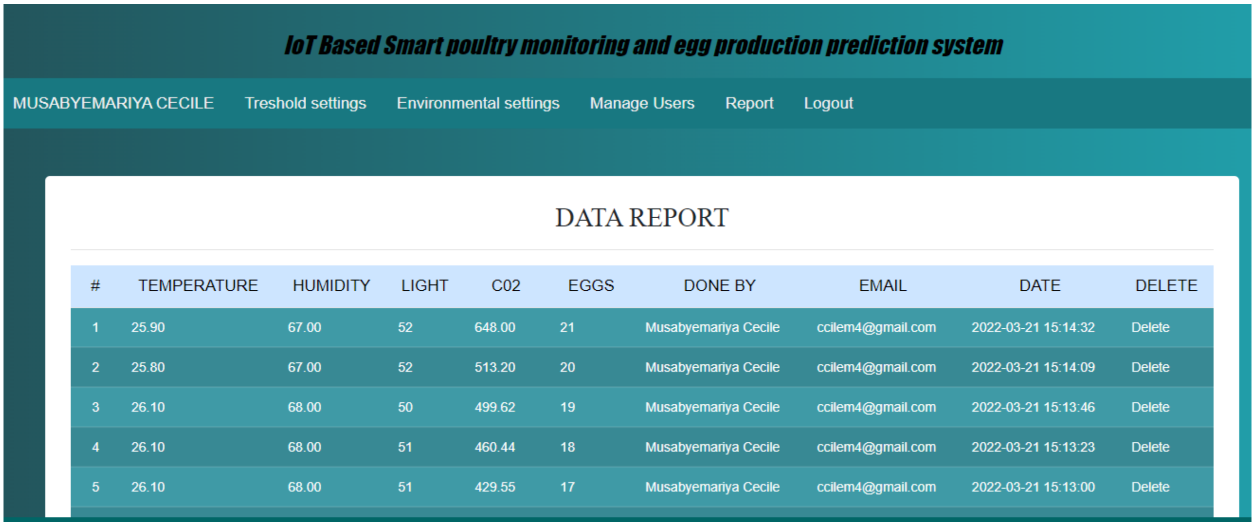


Figure 18. Summary of the system's level

In order to get the environmental parameters and the status of the poultry house, the farmer chooses environmental settings from home interface and the result is shown in figure. The data shown in figure are data captured by sensors deployed in poultry house and sent through GPRS communication system.



#	TEMPERATURE	HUMIDITY	LIGHT	C02	EGGS	DONE BY	EMAIL	DATE	DELETE
1	25.90	67.00	52	648.00	21	Musabyemariya Cecile	ccilem4@gmail.com	2022-03-21 15:14:32	Delete
2	25.80	67.00	52	513.20	20	Musabyemariya Cecile	ccilem4@gmail.com	2022-03-21 15:14:09	Delete
3	26.10	68.00	50	499.62	19	Musabyemariya Cecile	ccilem4@gmail.com	2022-03-21 15:13:46	Delete
4	26.10	68.00	51	460.44	18	Musabyemariya Cecile	ccilem4@gmail.com	2022-03-21 15:13:23	Delete
5	26.10	68.00	51	429.55	17	Musabyemariya Cecile	ccilem4@gmail.com	2022-03-21 15:13:00	Delete

Figure 19. The environmental parameters and the status of the poultry house

The farmer also is able to read some of poultry data from LCD screen.

Figure 20. The poultry data from LCD screen

4.3 Model Training and Evaluation implementation for eggs prediction

In this section, dataset used are Temperature, humidity, sunshine hours, carbon dioxide (CO2), ammonia, eggs produced and quantity of chickens taken as sample for this study. The dataset used contains 271 samples that include six features known as independent variables and one target variable also known as dependent variable which is called eggs. Those data are stored in CSV file to be imported for training and testing with different algorithms. The sample of dataset is shown in figure 4.21.

	A	B	C	D	E	F	G
1	Temperature	Humidity	Hours_sunsh	CO2	Ammonia	Eggs	Chickens
2	16	75	4.8	415	321	90	100
3	16	75	4.8	415	321	90	100
4	16	75	4.8	415	321	90	100
5	17	75	4.8	415	321	90	100
6	15	75	4.8	415	321	90	100
7	17	75	4.8	415	321	90	100
8	15	75	4.8	415	321	90	100
9	17	75	4.8	415	321	90	100
10	16	75	4.8	415	321	90	100
11	17	75	4.8	415	321	90	100
12	17	75	4.8	415	321	83	100
13	17	75	4.8	415	321	83	100
14	17	75	4.8	415	321	83	100
15	17	75	4.8	415	321	83	100
16	16	75	4.8	415	321	83	100
17	15	75	4.8	415	321	83	100
18	13	75	4.8	415	320	83	100
19	15	75	4.8	415	320	83	100

Figure 21. The dataset and testing dataset using sklearn python package

The training process and evaluation was done by importing the original dataset from CSV file by using data frame implemented with panda's python library module. The dataset was divided into two datasets, training dataset and testing dataset using sklearn python package. The training dataset contains 80% of original dataset, and the testing dataset contains 20% of the original dataset. The training dataset was applied to the machine learning algorithms in order to obtain desired predictive model. Testing dataset was used to verify if the predictive model does not under-fitting or over-fitting [34]. The over fitting occurs when the predictive model predicts well on the training data but does not do the same for new data or unseen data. The training and evaluation process has been done using Jupiter notebook software package provided by anaconda distribution software.

The training and evaluation process were implemented through python programming codes and python libraries. Diverse machine learning algorithms used were implemented using python and its libraries found in sklearn python package [35]. Sklearn was used to split dataset into training and testing dataset. Only 3 machine learning algorithms where selected because they present the highest accuracy compared to other tested models. Those models are decision tree, k-nearest neighbor, and linear regression. The dataset used in model training and evaluation have six inputs features and one output or target variable. The model inputs or independent variables include carbon dioxide, temperature, humidity, hours sunshine, and chickens.

```
In [63]: data.plot()
Out[63]: <matplotlib.axes._subplots.AxesSubplot at 0x243f22d7808>
```

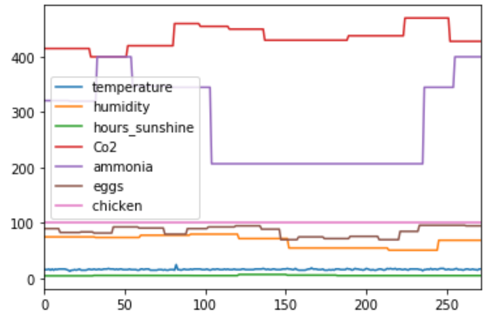


Figure 22. Dataset visualization in Jupyter notebook

Prior to applying the inputs data to the desired machine learning algorithm, data normalization was performed for improving the prediction accuracy by decreasing the high differences between the model independent variables for allowing the model to generalize on the new or unseen data. The 80 and 20 percentages of the original dataset were used as the training and testing datasets respectively.

```
In [105]: data=pd.read_csv('cecile.csv')
          data.head()
Out[105]:
```

	temperature	humidity	hours_sunshine	Co2	ammonia	eggs	chicken
267	16	69	5.2	428	400	95	100
268	16	69	5.2	428	400	95	100
269	15	69	5.2	428	400	95	100
270	17	69	5.2	428	400	95	100
271	17	69	5.2	428	400	95	100

Figure 23. The linear regression model machine learning algorithms during of model

The description of different the keywords used in prediction

Dataset size: 271 samples

Training data size: 216 samples = 80% of dataset/for each model

Testing/evaluation data size: 52 samples = 20% of dataset/for each model

Model features: CO2, temperature, humidity, ammonia, number of chickens

Model target: Eggs

Random state: parameter considered during of selecting training and testing data

4.4 Algorithms trained for prediction

The results appeared in the figure were generated using linear regression model machine learning algorithms during of model's training and evaluation process. The predictive accuracy was taken as the machine learning evaluation metric to assess the performance of the predictive model. It is clear to figure out that the predictive accuracy is improved as the number of iterations increase progressively for both training and testing data. The accuracy obtained tend to be near 85 % with linear regression.

```
In [110]: plt.plot(r_state,train_accuracy)
          plt.plot(r_state,test_accuracy)
          plt.title("LINEAR REGRESSION MODEL EVALUTION FOR EGGS PREDICTION")
          plt.xlabel('RANDOM_STATE')
          plt.ylabel('EGGS PREDICTION ACCURACY')
          plt.legend(['Train_accuracy','Test_accuracy'],loc='best')
          plt.show()
```

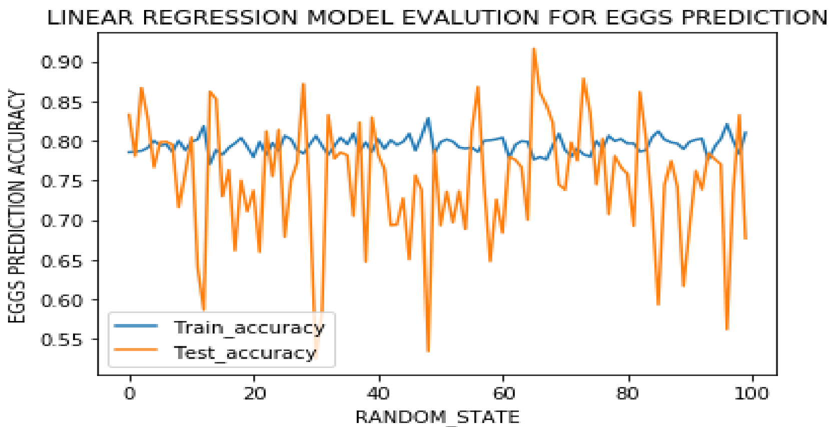


Figure 24. Linear regression model evaluation

The accuracy tends to be around 85% when we use k-nearest neighbor machine learning algorithm.

```
In [111]: plt.plot(r_state,train_accuracy)
          plt.plot(r_state,test_accuracy)
          plt.title("K-NEAREST NEIGHBORS MODEL EVALUTION EGGS PREDICTION")
          plt.xlabel('RANDOM_STATE')
          plt.ylabel('EGGS PREDICTION ACCURACY')
          plt.legend(['Train_accuracy','Test_accuracy'],loc='best')
          plt.show()
```

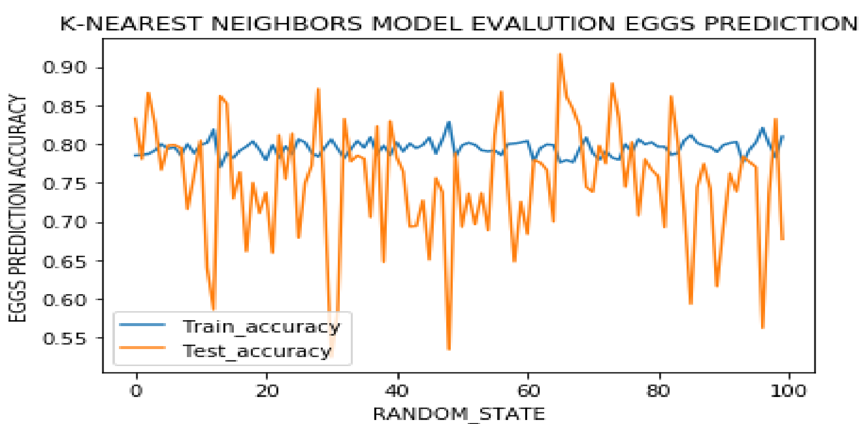


Figure 25. K-nearest neighbors model evaluation

When decision tree machine learning model is used, both the training and testing accuracy became roughly around 90 %.

4.5 Algorithm chosen for our study

The purpose of using machine learning in this study was to be able to predict the eggs production rate based on historical data. The analysis was done using k-nearest neighbor model, decision tree and linear regression model with the prediction accuracy of 85%, 90% and 85% respectively. Decision tree outperforms other models tested in this study. The obtained accuracy is accurate compared to the original dataset collected during the data collection. The accuracy can be increased with the increase of dataset used because the more the dataset get higher, the more the model is well trained to provide accurate results [36].

4.6 Prediction

After analyzing data from research, we have noticed that the decision tree algorithm is the model which presents high accuracy based on dataset shown in appendices and those data helped us to predict for future egg production though Orange app.

In order to get insight for future egg production, the farmer downloads the current data uploaded to ThingSpeak or MySql database in form of CSV file, then the farmer uses that file in orange app. The sample of the file from file used for prediction is shown in figure 4.28 to predict for future egg production by taking temperature in column 1, humidity in column 2, sunshine hours in column 3, CO2 in column 4, ammonia in column 5, eggs in column 6 and number of chickens in column 7 respectively. Eggs was taken as target of algorithm and other parameters are taken as features of model. That sample file shown in figure 4.28 is the dataset used in orange app in order to predict future egg production.

17	75	4.8	415	320	420	450
15	75	4.8	415	320	420	450
15	75	4.8	415	320	450	475
15	75	4.8	415	320	450	475
15	75	4.8	415	320	450	475
16	75	4.8	415	320	450	475
17	75	4.8	415	320	450	475
16	75	4.8	400	320	450	475
16	75	4.8	400	320	450	475
17	75	5.5	400	320	450	475
16	74	5.5	400	320	450	475
16	74	5.5	400	400	460	475
17	74	5.5	400	400	460	475
16	74	5.5	400	400	460	475
16	74	5.5	400	400	460	475
17	74	5.5	400	400	460	475
17	74	5.5	400	400	470	475
17	74	5.5	400	400	479	500
18	74	5.5	400	400	479	500

Figure 26. Prediction in orange interface

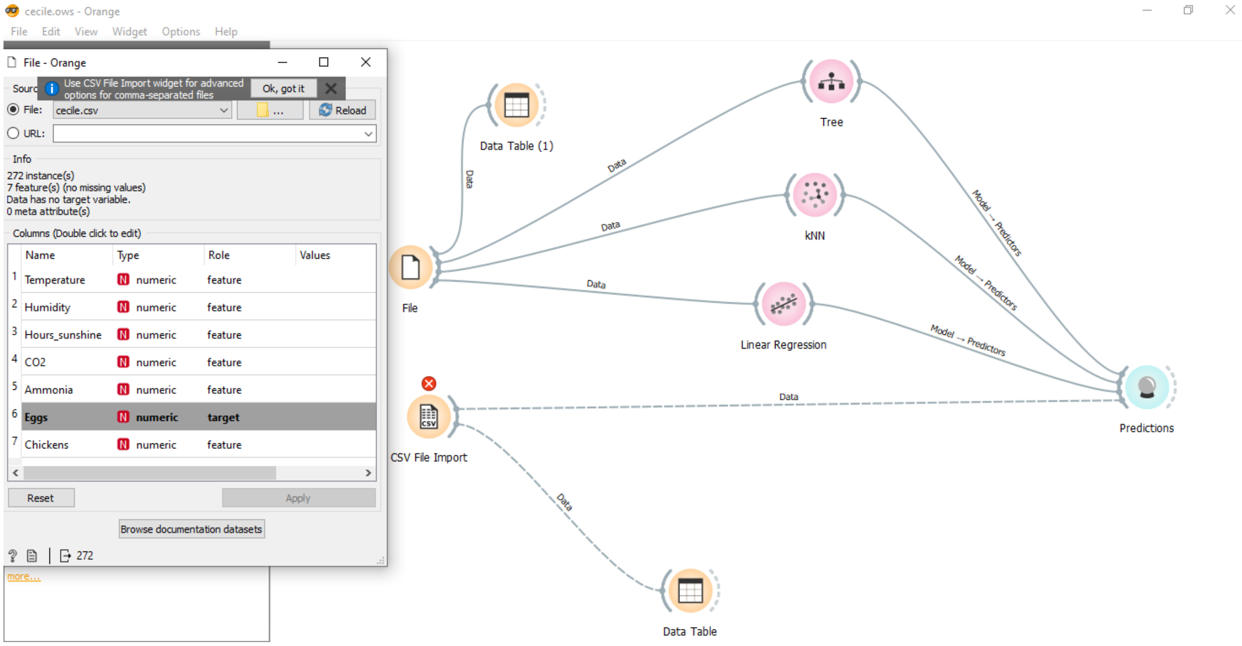
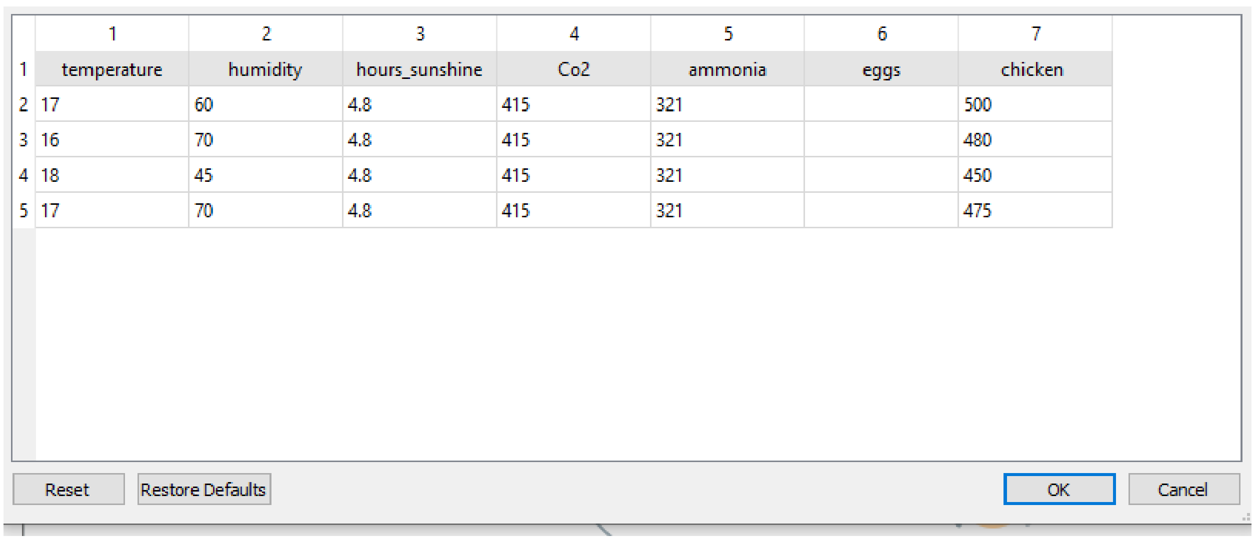


Figure 27. Classification of parameters into features and target

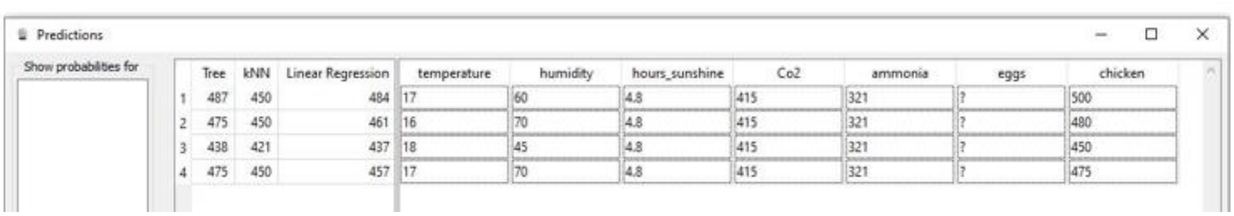
The table asking how many numbers of eggs to be produced when we have 500, 480, 475 and 475 chickens under the parameters.



	1	2	3	4	5	6	7
1	temperature	humidity	hours_sunshine	Co2	ammonia	eggs	chicken
2	17	60	4.8	415	321		500
3	16	70	4.8	415	321		480
4	18	45	4.8	415	321		450
5	17	70	4.8	415	321		475

Figure 28. Eggs prediction

The predictions as the result given by Three machine learning models used in our study.



	Tree	kNN	Linear Regression	temperature	humidity	hours_sunshine	Co2	ammonia	eggs	chicken
1	487	450	484	17	60	4.8	415	321	?	500
2	475	450	461	16	70	4.8	415	321	?	480
3	438	421	437	18	45	4.8	415	321	?	450
4	475	450	457	17	70	4.8	415	321	?	475

Figure 29. Results of prediction

Temperature: 18 degrees Celsius

Humidity: 74 %

Sunshine hours: 5.5 hours

CO2: 400 rpm

Ammonia: 400 rpm

Eggs: 479

Chickens: 500

and the first row in the figure 4.30 where we want to know how many eggs should be produced when:

Temperature: 17 degrees Celsius

Humidity: 60 %

Sunshine hours: 4.8 hours

CO2: 415 rpm

Ammonia: 321 rpm

Eggs: ?

Chickens: 500

The result of prediction in figure 4.26 shows that decision tree gives prediction of 487 eggs, KNN gives prediction of 450 eggs and linear regression gives prediction of 484 eggs.

4.7 Cost effectiveness of prototyped system

The adoption of the designed IoT based smart poultry monitoring and egg production prediction system helps farmers to save money and time. It requires a farmer to invest once in buying automated system. The prototyped system operates most of all works that ordinary worked with full intervention of human such as controlling environmental parameters to the adequate level for hens, feeding and watering hens, counting eggs, record poultry farming data and prediction of future egg production. With the use of the automated system, the farmer save labor cost and money spent to manpower resources, the poultry operations are improved efficiently and effectively that leads to increased egg production then the farmer earns much money.

CHAPTER V: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this dissertation, IoT Based Smart Poultry Monitoring and Egg production prediction system was developed to automate and make poultry operations to operate efficiently and predict egg production. The main goal of this project was to design IoT Based Smart Poultry Monitoring and egg production prediction system in order to make poultry farming more profitable in Rwanda.

The system will help farmers to control the farm remotely. Based on the environmental parameters in the poultry house or there is an egg laid at a given time, the system will open or close the pump, food container, heater, fan, and record the number of eggs in a database and the message will be sent to the farmer to update him with the status of the farm. By using this system, a farmer will save money. This will lead to increase in productivity of eggs as well as good management of information related to the farm.

5.2 Recommendations

Based on the outcomes of the system, we recommend other research to handle the issues of PIR sensor in counting eggs which can count the other things that pass in the region where the sensor is placed and it reduces the inaccuracy of the total number of eggs. We also recommend for the future research to improve the system with feature of cleaning the house automatically which will decrease the presence of gases in the farm. And we recommend future researchers to deploy machine learning algorithm in web application for easy work of predicting in separate application.

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