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COLLEGE OF SCIENCE AND TECHNOLOGY

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

Research thesis title:

IoT-Based Cow Health Monitoring System for early Detection of Foot and Mouth Disease, Case of Eastern Province, Rwanda

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Award of Masters of Science Degree in Internet of Things-Wireless Intelligent Sensor Networks.

Submitted by

NIRERE Gaudence

Reg. No: 220013253

March, 2022

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Co-Supervisor: Prof. KAYALVIZHI Jayavel

March, 2022

DECLARATION

I declare that this Dissertation is my original work and contains my work. As required by rules, I have appropriately cited and referenced all non-original results and materials in this work.

Name of the student

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Reg. No: 220013253

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Date:14/03/2022

CERTIFICATE

This is to certify that the project work entitled **"IoT-Based Cow Health Monitoring System for Early Detection of Foot and Mouth Disease, Case of Eastern Province, Rwanda"** is a record of original work completed by **NIRERE Gaudence** with registration number: **220013253** in partial fulfillment for the award Masters of Science in Internet of Things in the college of Science and Technology, University of Rwanda during academic year 2019-2021. This work has been submitted under the guidance of Dr MASABO Emmanuel and Prof. KAYALVIZHI Jayavel.

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ABSTRACT

Nowadays, Rwanda is becoming the country where the technology is integrated in agriculture and livestock domains to easily enhance the life conditions of every Rwandan for wellbeing. With the technology development, cow's health and early diagnosis of disease have gained the importance in agriculture and livestock domains. It is a popular implementation to monitor cow's health, particularly foot and mouth disease detection. The existing technology solutions covered only the cow's health monitoring by the use of rectum thermometer to observe the body temperature and the ear tag mounted on the cow's ear to monitor the identity of each cow. Thus, farmers are using the traditional system for controlling the unpredictable killing diseases as cows are freely moving in the farm and employees visit them again by again for observing their health condition so it is so difficult to consult them and suggest treatments in real time. An advance monitoring system in which, mobile and wireless sensors networks are capable of bringing a new way of controlling the cow's health instead of using many employees in doing that task physically in large farms. An IoT-based cow health monitoring system is used to track data such as body temperature, lameness, and location. Sensors are used for capturing the body temperature and lameness related to the cow behavior where the data are collected, analyzed using fuzzy inference system and the results can be stored in cloud. This work estimates an alert system to notify early the veterinary doctor or farmer when abnormal values are leading to the foot and mouth disease and to prevent its spread. The results can be viewed in internet on interfacing Node Mcu 8266 Wi-Fi and in mobile application to provide full information and treatments at real time in which will show the live updates in Web App through the dashboard.

LIST OF ACRONYMS

AVR: Automatic Voltage Regulation

CMOS: Complementary Metal Oxide Semiconductor

CPU: Central Processing Unit CPU

FMD: Foot and Mouth Disease

FMDV: Foot Mouth Disease Virus

GPRS: General Package Radio Service

GPS: Global Positioning System

GSM: Global System for Mobile Communication

IDE: Integrated Development Environment

IoT: Internet of Things

LoRaWAN: Long Range Wide Area Network

MATLAB: Matrix Laboratory

OS: Operating System

PDMT: Precision Dairy Monitoring Technology

RAB: Rwanda Agriculture Board

RSIC: Resilient Sound Isolation Clip

SIM: Subscriber Identification Module

WSN: Wireless Sensor Network

Table of Contents

List of Figures

List of Tables

Chapter 1: GENERAL INTRODUCTION

1.1 Introduction

Some African countries, such as Rwanda, have benefited significantly from livestock farming. [1], and it is the fastest growing agricultural subsectors at the moment. There are 1,194,895 cattle, 1,270,903 goats, 371,766 sheep, 211,918 pigs, 498,401 rabbits, and 482,124 poultry in the current animal population [2]. The focus of this study was on cattle, particularly cows from the Eastern and Southern regions. The government is targeting the predominant livestock production system, particularly in milk production, to increase milk consumption from 40 to 80 liters per person per year by [3], and projects milk production from 653 million liters in the base year to 1.12 billion litters in 2021/2021 due to modern farming methods. Even if there is a projection of increased milk production, farmers in Rwanda face serious challenges such as foot and mouth disease , mastitis bacterial disease, and worms infectious viral disease, all of which affect milk production, with foot and mouth disease posing a significant challenge to the cattle subsector in Rwanda in many parts of the Eastern Province [4].

As a result of the poor health of their cows and the lack of excellent experienced veterinary experts, farmers are suffering from a lower and inferior milk product. Employees have limited time to examine cows and look for signs of fatal diseases that aren't yet known, making daily monitoring of cow's health status in farms increasingly challenging. The present monitoring was conducted physically, with humans observing the cows' daily routines. They can identify health-related diseases this way, but it is not always effective, especially if you have to monitor the health condition of a many cows in a large farm, because there is still no information exchange with the Internet of Things to help cow farmers monitor cows automatically.

As a result, farmers must implement a low-cost, high-efficiency system for cow health monitoring in order to boost milk output, control and instantaneously detects diseases, and accurately prevent disease spread. They must address this problem by making wise decisions about replacing old farming practices with new advanced technology including Wireless Sensor Networks architecture, which consists of sensor nodes, gateways, and information technology.

As it is used in various areas, the Internet of Things, a mature and successful technology, is offered as one of the answers to agricultural and livestock's low efficiency and productivity. Surveillance of cattle is necessary [5].

1.2 Background and Motivation

Foot and Mouth Disease (FMD) is highly contagious viral disease caused by the Foot and Mouth Disease Virus (FMDV), a picornavirus [6]. Rwanda's Eastern Province, which covers 9813 square kilometers and is characterized by a farming system with around 500,000 cows, 500,000 goats, 13,000 sheep, and 130,000 pigs, is the country's largest [7]. In this province, Foot and Mouth disease is a big issue, especially during the dry season, which is when outbreaks are most prone to develop. Foot and mouth disease reduce milk output, resulting in negative consequences for producers in the livestock industry. Because it is difficult for cows to monitor their health and predict the exact type of disease, some vital signals, such as body temperature, which is a crucial physiological measure and an indicator of dairy health, can be used to anticipate the disease [8] and lameness which will conduct to the Foot and Mouth disease.

This difficulty allows the Rwanda Agriculture Board (RAB) to establish the way of taking care of suspected attack of foot and mouth disease and measurements before being spread out. As a result of these difficulties; there is a way to monitor cow health from their farms. This is done by using an IoT-based system that will monitor the body temperature (high fever) and the lameness associated with the weakly events of activity of standing or laying events referring to the abnormal walking [9], where these two parameters are considered as the basic vital signs which lead to the foot and mouth disease. Therefore, the farm owner and veterinary doctor will be notified when abnormal conditions have occurred referring to the standard conditions of body temperature and lameness parameters for cow welfare.

1.3 Problem Statement

In recent years, farmers are suffering from insufficient milk production, illness or diseases of their cows which may cause uncertain death and affect their economy[10]. Many researches realize that the cow which is not in good condition, can manifest different abnormal behaviors such as high temperature and fewer movements where it can refuse to eat and move.

In that case, the production of milk will be reduced [11][12].

Thus, it is very difficult for farmers and veterinary doctors to identify the cause of these behaviors as they use traditional techniques, where it requires continuous surveillance or day-to-day observation which request much time and a big number of workers or employees for that hard work [13]. By using the technique of manually diagnosis, they can identify the variation of the health parameter (behaviors) but this does not show exactly the illness or disease to treat.
Therefore, this system technique may lead to false observations because they are guessing and may lead to wrong results as they can confuse vital signs which may differ from actual health conditions of the cow, where two diseases can have the common signs but differ from one or two signs [14]. This can cause a complication effect on the cow's health, so there is a need for an automated health monitoring system that will maintain the data information from the parameters, fast and efficiently. Therefore, the proper treatment can be used in real-time to prevent unpredictable diseases, illnesses, and undesired death of cows [15]. Cow diseases become a critical challenge in livestock, especially in cows.

According to the Rwanda Agriculture Board (RAB) guidelines, disease in cows is defined as any illness which may harm the cow and which can be spread from one cow to another in the same region or different regions[7]. RAB advised the farmers to give regularly give the medicine to their cows like those of intestinal worms but they didn't have a positive effect for those which are affected by bacteria or viruses. This project will provide farmers and veterinary experts with a long-term solution for monitoring the body temperature and lameness of cows in order to diagnose foot and mouth disease utilizing data collected and analyzed using an Internet of Things (IoT) system. It will also provide a solution for the Rwanda Agriculture Board to have an image of foot and mouth disease in livestock, particularly cows. They will be able to monitor the body temperature and lameness vital signs from the cow's body using the IoT system and report to the farmers or veterinary doctors as the system's concerned people, who will then take care of them as soon as possible.

1.4 Study Objectives

1.4.1 Aim

The purpose of this research is to develop an IoT-based cow health monitoring system that analyzes collected data to detect Foot and Mouth disease and sends a real-time notification to the farmer or veterinary doctor if the cow's health deteriorates.

1.4.2 General Objectives

To design an IoT-based real-time monitoring system for cow vital signs in order to diagnose and manage foot and mouth disease early in Rwanda.

1.4.3 Specific Objectives

- To design a system simulation model for prototyping that will be used by farmers and veterinary doctors to detect cow's infected with foot and mouth disease in real-time;
- To analyze the body temperature and lameness vital signs variations provided by the sick cow for foot and mouth disease detection using fuzzy inference system;
- To determine the foot and mouth disease notification process to farmers or veterinary doctors by text message in the event of abnormal conditions with the location.

1.5 Hypothesis

A new IoT –based cow health monitoring system will help the early detection of foot and mouth disease, which is characterized by a high body temperature (high fever) and abnormal lameness. Farmers and veterinary doctors will be able to monitor the health of cows based on changes in these vital indicators, which can lead to foot and mouth disease, and make real-time decisions to prevent the disease from spreading.

1.6 Study Scope

This system is going to focus on detecting foot and mouth disease based on the body temperature and lameness parameters when it is making the abnormal variations until the owner farm or veterinary doctor will receive the notification message to treat in real-time. From the input to the output, the system will be able to detect foot and mouth disease.

1.7 Significance of the Study

This system is IoT-based cow health monitoring, which aims at preventing the delay of recognizing the foot and mouth disease and taking care of cows in large farms in Rwanda. This will prevent the uncertain death of the attacked cows and the less and poor production of milk when it is recognized late. Economically due to the high illness or diseases which causes the death of the cows, the farm owners are suffering from financial instability due to the loss of their cows[16].

So, this system will help them to monitor the abnormal conditions of the body temperature (fever) and the lameness parameters as vital signs in real-time which will result in the detection of foot and mouth disease and taking treatment early before spreading out in all farm or in neighbor farms.

In the livestock sector, there will be a significant reduction in the number of dead cows and fewer production of milk , all caused by foot and mouth disease[17]. Furthermore, this system will simplify the work to the farmers and veterinary doctors where they will be able to identify the cause of the high fever, fewer movements and low production of milk and what these indications can symbolize or lead for.

Decisions will be taken based on the information delivered by the system. Based on the system's statistics, it will also lead to greater precautionary actions against foot and mouth disease in Rwanda.

1.8 Organization of the Study

This section includes all parts of the thesis. Below are the parts:

Chapter one provides an overview of the research which includes the study's history and its motivation, study objectives, study hypothesis, study limits and research interest.

Chapter two discusses related researches that were carried out before, their gaps and how this research is going to improve and fill the existing research.

Chapter three is the research methodology. It gives an overview of the research methods that will be used in this work. It also presents the requirements needed in this work.

Chapter four discusses analysis and design that includes all theories used in this research.

Chapter five provides results and analysis by interpreting data using graphs.

Chapter six finalizes the research with a conclusion and suggests some recommendations for future work.

1.9 Conclusion

In this chapter, the researcher has provided an introduction to the research, the study's history and purpose, a detailed problem statement, the research's scope and limitations, how the research is organized, and why the researcher is interested in working on this research.

Chapter 2: LITERATURE REVIEW

2.1 Historical Background

Normally, it is time-consuming for farmers to visit the farms day-to-day and often requires a veterinary doctor to seek for the appointment in weeks or months. Even farmers may feel that it is not necessary to spend money by receiving the frequent visit of veterinary doctors, but merely wish to send the illness of the cow as cow diseases requires regular communication to the veterinary doctor. It would therefore sound good if a sick cow is controlled remotely and get early treatment through the farmers or invigilators as well. Hence the growth of technology especially in IoT and its integration can be a good practice if it is integrated into farming fields. There are many interesting researches about cattle health monitoring dealing with controlling cattle in large farms using Internet of Things as they are subdivided in different subsections.

2.2 Section 1, Practices and challenges in cow health monitoring

The wearable device's smart sensors, which include heart rate sensor, body temperature sensor, and accelerometer sensor for lameness, are incorporated with other components to collect sick cow data. [18].

Bharat Singh Thakur[19] proposed the system to solve the problem in the milk business due to the absence of information as well as lack of understanding the health and wellbeing of the cattle. That system was consisting of farm automation in monitoring the wellness of the cattle using the IoT-based environment and health parameters including body temperature and heartbeat parameters.

The research of M. Lee [20] , presented the system to help farmers or veterinary doctors to control the health of their cows' day to day in large farm using Internet of Things (IoT). That system was designed to handle the problem of time spending by employees to surveillance all activity of the cow, and to know if there is any attack of illness and to know the status of the estrus for their cows. The Internet of Things (IoT) research Based on cattle health and environment monitoring, it was emphasized how difficult it is to monitor numerous bovine health measures such as body temperature, heartbeat, and location in any setting.

Then system proposed consisting of sensors that are used to collect information and measures about all activities and health of the cattle continuously to take decision in order to increase the milk production and early preventing different disease [15].

Kumar Suresh K proposed a system [21], based on the observation of the cattle's health by comparing the present health condition required for normal cattle based on parameters like, heartbeat, temperature and pressure compared with standard parameters and information is transmitted through Internet of Things (IoT).

More parameters are considered to form a system which allows the prior detection of possible disease developed by Shivank Vyas, Shukla Vipin, and Nishant Doshi [22]. The Internet of Things is used to solve the problem of early detection of foot and mouth disease and mastitis disease in cows using various sensors and Machine Learning Algorithms Machine Learning.

2.3 Section 2, Use of IoT based technology in cow's health monitoring

Chen Pei [23] proposed the system for the cow estrus by examining the physical status of the cow, such as temperature, which would fluctuate considerably during their estrus, and transmitting the data using characteristics such as temperature, humidity, and heartbeat, detection based on Narrow Band Internet of Things Narrow (NB-IoT) communication can be made.

Internet of Things technology is illustrated [24], for farmers using sensors to collect transfer it to the Arduino Uno. All hardware components and sensors will read the results through the computer monitor and use the global positioning system to track the current status and location of the cattle (GPS).

S. Shetty, P.K, A.K explained also the Internet of Things system technology known as Currently, Precision Dairy Monitoring Technology (PDMT) installed in local and remote locations of farmers. The system has the purpose of mapping the special aspects of the animal behavior like temperature and heart rate using sensors and data is aggregating and reporting to the health center where farmers can retrieve information accordingly [25].

LoRaWAN technology is proposed to monitor Livestock diseases [26] resulting in a drop in agricultural income due to poorer farm output, the development of chronic diseases, or even culling. In addition, cattle diseases are monitored where the aim was prediction and taking decision at real time based on the variations of body temperature using biosensor.

Midhya Raj, Anitha Priya and Dona Francis [27], proposed a system solution for cow health monitoring using zigbee technology and data information is collected by sensors and the output of these sensors is being transmitted via zigbee.

The online system is proposed that helped farmers to monitor different activities on their cattle like keeping a watch on some important parameters. In this work, health condition of individual cattle like abnormal behavior which leads to the illness and the accelerometer is used to monitor these activities in manner to provide the treatment of sick cattle at real time [28].

2.4 Section 3, IoT based cow disease detection

The biosensor technology was the system designed automatically to address to the lack of reliable for early detection of diseases in farms as the rapid detection is a key health for taking care of cattle daily. It was proposed the system where data are collected on physiological parameters, fam environment and health behavioral where the problem in lack of taking care the cattle at real time and rapid detection of any disease or illness are solved [29].

The authors of this research paper [30], focused on how the Internet of Things can be implemented in way of livestock monitoring where they proposed the system be used to monitor location and different disease where health parameters such as temperature, blood pressure measurement, and environment parameters like temperature, and humidity are monitored in place animals are kept.

B. Achour, M. Belkadi, R. Aoudjit, and M. Laghrouche [31], also explained in their work, the IoT and sensors technology used for easily detection cattle diseases and dairy cow behavior monitoring using non-invasive sensors to improve the welfare and health of cows in smart farm.

2.5 Section 4, IoT based cow disease notification and tracking

Seema Kumari and Dr. Sumit Kumari Yadav [32] have designed and developed a prototype of smart animal health monitoring system based on IoT for real time monitoring various parameters.

The system prototype is developed by mounting different sensors on the body of a cattle to give information about the farm's health status, and the owner farm can simply retrieve such data and being notified through the text message using GSM. The system consisting different smart sensors [33], has been proposed to handle the issue of getting the information at real time using the advance monitoring system where the sick cow will be able monitored remotely his vital signs and the veterinary doctor or the farmer will receive the notification of abnormal measurements on this mobile phone and then propose accordingly.

S. Lin, Z. Ying, and K. Zheng proposed the system used to monitor the cattle health where data are collected and transmitted based on LoRa technology. Sensors are used to capture activity and location data in real time and then data are transmitted to the cloud server through the microcontroller. The farmer or veterinary doctor will access all history, current healthy information and track their cattle [34].

Famers are suffering from less production in milk due to the cattle affected by various types of diseases. Thus the solution system is elaborated to monitor those diseases using Internet of Things [35] where the system consisting of a microcontroller connected with sensors. Different parameters are monitored and the farmers received the notification in case of abnormal condition.

B.R. dos Reis , Z. Easton, R.R. White and D. Fuka [36], proposed the system having the objective of rapidly deployment of long range radio (LoRa) based sensors, that can be used to track location and activity of livestock in farm. The system consisted of a microcontroller, a generic motion sensor, generic GPS receiver and generic LoRa radio.

In these researches, it was discovered that previously proposed systems lacked significant analytics and intelligence, resulting in gaps between the system's desired requirements and the proposed solution, where they used to grant network connectivity but did not consider real-time analytics. They use an offline analysis technique to process and interpret previously gathered data, which isn't ideal for real-time monitoring of dairy cow health. So this project will come up with the solution that farmers or veterinary doctors will be able to monitor cow behaviors (body temperature and lameness) and taking decision anywhere and anytime based on the analysis of collected data as well as the detection of foot and mouth disease related to the vital signs or cow behavior.

Chapter 3: METHEDOLOGY AND MATERIALS

3.1 Introduction

This section provides an outline of the research methods that will be employed throughout the project. It displays the processes and procedures employed throughout the project, as well as how the analyzed results were presented. The majority of research methods are scientific, however because data analysis is a part of this study, both qualitative and quantitative approaches are rarely used. This research method is classified as scientific research methods, and it suggests that scientific research methods are just employed for clarifying purposes.

3.2 Development Research Approaches

3.2.1 Scientific Research Approach

Several scientific methodologies were employed in the course of this investigation. The present schemes were discovered via qualitative research approaches, and an experimental approach was employed for design, analysis, and simulation. It began with a jumble of thoughts, and over time, the researcher came up with the objectives, problem definition, and proposed solution. This aided in the development of knowledge regarding research ideas in the existing projects. Existing techniques in this situation took advantage of the chance to identify existing information and suggest a solution to the given problem. To be more precise, a quantitative method was used to assess how other existing schemes operate, as well as their shortcomings, in order to determine what may be done to improve their performance. Several concepts were developed and considered, including the use of an Internet of Things-based Cow Health Monitoring Simulation as a prototype, which will allow the system to detect foot and mouth disease early when abnormal vital signs appear.

3.2.2 Experimental approach

First and foremost, the idea of this project came with the objectives, a description of the problem statement, and its solution based on the IoT application.

The designed project consists of IoT Based Cow Health Monitoring System where foot and mouth disease is early detected using the fuzzy inference system for body temperature and lameness (motion behavior or footsteps) parameters.

The data information to be used are cow’s health parameters like body temperature and lameness(footstep) relationship for cow’s health. The body's cow will be used to capture environmental temperature and lameness data. The gathering of information will allow the farmers to have full control to their cows and monitor them via IoT cloud platform. Data collection tools will be used such as interview and documentation. To offer statistical analysis, the Fuzzy Logic Model, and MATLAB tools will be used.

This will help for early detection of foot and mouth disease when the body temperature and lameness parameters are becoming abnormal by comparing with the normal levels automatically and these abnormality cases will be notified to the veterinary or farmer through the text message. During this research, the researcher tried to identify the normal measurements for both parameters, and the measurement results are shown in chapter four of this research.

3.3 Design and System Development Methodology

3.3.2 Prototype model

- **Simulation**

The simulation model is a technique of watching something happen without it actually happening, and it may also be used to forecast what might happen without actually doing it, in case it's too risky, expensive, or complicated. It can also be used to demonstrate what will happen next or what has already occurred. A simulation model's purpose is to reveal the underlying mechanisms that influence a system's behavior. The simulation model is used to evaluate products (and product concepts) before investing a significant amount of time and money on the final product. [37].

- **Prototype**

The prototype model is a method of system development that does not necessitate the requirement being frozen. A prototype is a sample that is used to test the procedure. Early on in the project, the software designer and implementer can gather useful feedback from users by prototyping. The prototyping model was chosen as the study strategy for this project, which is a system development method (SDM) in which the project is planned, built, tested, and then repeated until it provides a valid final solution[38].

3.3.3 Prototyping model steps

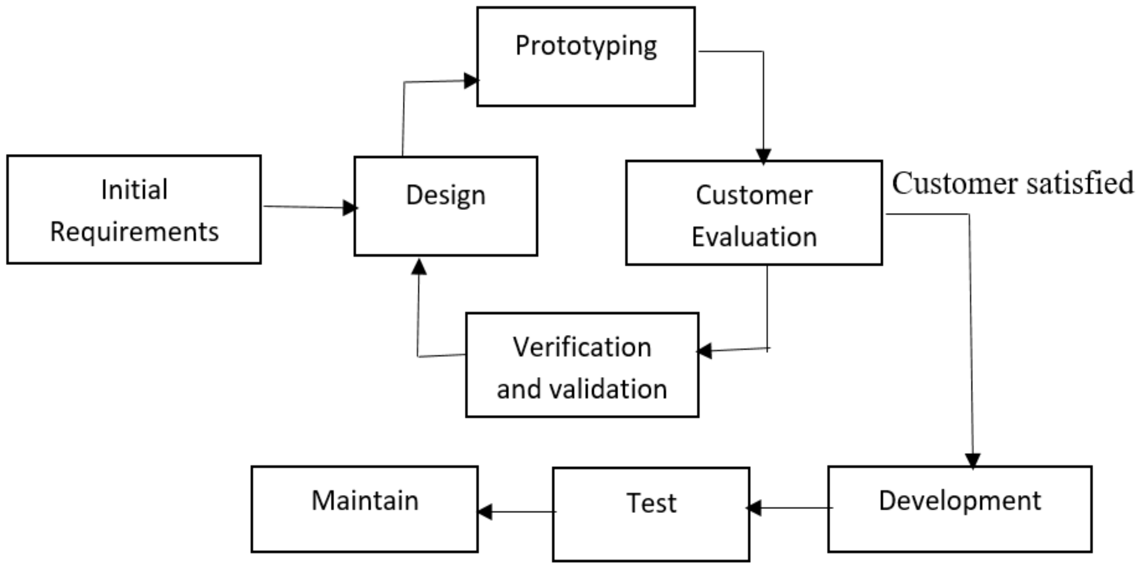

Fig 3.1 Prototype model

- **Initial requirements:** The initial stage in the prototype process is to study the requirements. During this phase, the system's needs are thoroughly defined. As part of the early detection process for foot and mouth disease, farmers and veterinary doctors are interviewed to learn what they expect from the system.
- **Design**: It is based on the concept of early detection. A preliminary design is the second phase, after knowing all of the requirements for IoT-based early detection of FMD. At this point, a rudimentary system design is constructed. It isn't, however, a finished product. It provides a short overview of the system to users. The design aids the prototype development.
- **Prototype:** An actual prototype is produced using the information acquired during the fast design phase. It's a scaled-down version of the required system. This is also where all of the prototype equipment, such as the microcontroller, sensors, gateway, cloud storage, GSM module, and other accessories, will be employed.
- **Customer evaluation:** At this point, the proposed system is presented to the user for an initial evaluation. It assists in determining the strengths and shortcomings of the functioning model. Customer suggestions and feedback are collected and delivered to the developer.

- **Verification and Validation:** If the customer is dissatisfied with the current simulated system, all user input and additions made by state recommendations on early detection of foot and mouth disease are collected and added to the project for enhancing it.
- **Development**: After the user has successfully accepted the simulation proposal, in this phase, the designed prototype is developed. Devices are connected together where the sensors will be connected to the microcontroller and by processing this with the help of a fuzzy logic system, it will allow the concerned to see the output in real-time.
- **Test:** Testing a system after development is a technique that involves creating a prototype, testing it, and tweaking it as needed until an acceptable result is attained, from which the whole system or product can be built.
- **Maintain**: When a system is developed based on a final prototype, it is rigorously tested before being sent to production. After then, the system is subjected to regularly to looking after in order to minimize interruption and avoid extensive failures

3.4 Data Collection Methods

Interview and documentation are the methods used in my research project. Interview and documentation. The researcher interviewed farm owners (farmers) and veterinary doctors about the current system used for diagnosing foot and mouth disease. Also, electronic books (from the internet), various journal articles, and conference papers are used.

3.4.1 Interview

In this phase, an unstructured interview method is used. Where few questions are asked aimed at better understanding the existing methods used for foot and mouth disease detection and obtaining more information about this disease.

3.4.2 Documentation

Documentation is the evidence provided for information and ideas borrowed from others. In this method, as pointed out above; electronic books, journal articles, conference papers were used and cited in this research project.

3.5 Proposed System Requirements

3.5.1 Functional requirements

Functions that the user requires from the system are known as Function requirements. The following functional requirements are applied to early detection of Foot and Mouth Disease with an IoT-based Cow Health Monitoring System:

1. Activate sensors to the microcontroller
2. Sensing output from the microcontroller
3. Display all signals being processed
4. Sending converted signals (data) to the cloud storage and monitoring platform.

3.5.2 Nonfunctional requirements

The proposed Adaptive Algorithm for IoT –based cow health monitoring system for early detection of foot and mouth disease also has the following non-functional requirements:

- **Reliability:** The IoT-based cow health monitoring system for early detection of foot and mouth disease analyzes body temperature and lameness measures, alerting farmers and veterinary professionals if crucial signs are confirmed (abnormal conditions).
- **Usability:** No more important knowledge is needed after the installation of this system. Except to know how to view data on the cloud. Here anyone with knowledge in ICT can look at this.
- **Scalability:** Because it can add different metrics depending on the goal, the IoT-based Cow health monitoring system for early detection of Foot and Mouth Disease is expandable. Other sensors that will improve performance can be added here by the researcher.

3.5.3 Requirements for Hardware and Software

3.5.3.1 Hardware requirements

- **ESP 8266-01 Wi-Fi module**

The EPS8266 01 is Wi-Fi module really useful, cheap for controlling devices over the Internet. It allows Microcontroller easily access to Wi-Fi network and it is one of the primarily incorporated Wi-Fi chip in the industry domain where it is capable of assimilating the antenna switches, radiofrequency, power amplifier, low nose receiver amplifier, and power executive elements[39].

It is less complicated as Wi-Fi module is used to monitor health of many cattle's at real time.

Fig 3.2 Wi-Fi Module

Table 3.1 Wi-Fi module Pinout

Pin	Description
VCC	3.3 V (3.6 V
GND	Ground
TXD	Transmit Data (3.3 V Level)
RXD	Receive Data (3.3 V Level)
CH_PD	Chip Power Down (LOW=Power down Active
GPIO0	General Purpose I/O 0
GPIO2	General Purpose I/O 2
RESET	Reset (Reset = LOW active)

- **Microcontroller ATmega328P**

With a vast number of pins and functionalities, the ATmega328P is one of the high-performance AVR technology microcontrollers. It has an RSIC CPU and an 8-bit CMOS processor which improves performance and power efficiency. It also includes auto naps and a temperature sensor built in. Internal protections and several programming techniques are included in this ATmega328 IC, allowing users to prioritize this controller for a variety of situations that are becoming more common every day [39].

The ATmega 328P is a 28-pin chip, as indicated in the diagram, with many pins serving multiple functions.

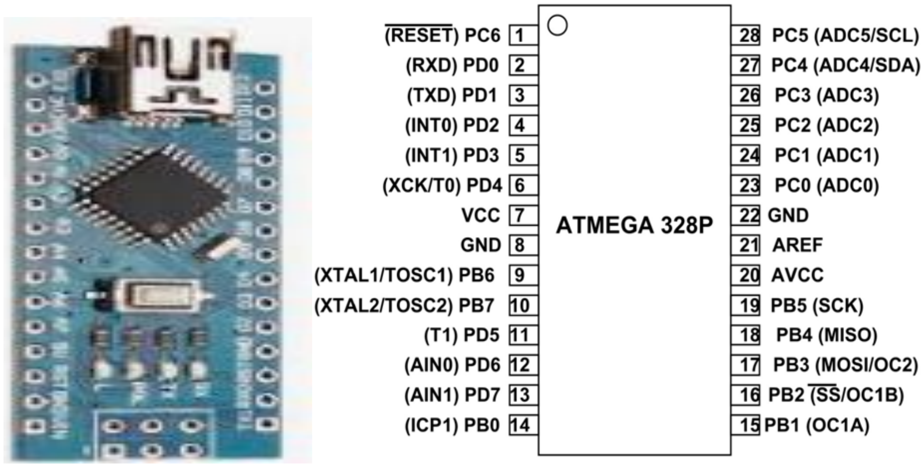

Fig 3.3 ATmega328P Microcontroller Pinout

- **Sensor Module MPU 6050 (Gyro-accelerometer)**

The MPU 6050 Gyro-accelerometer is a high-precision motion tracking device with low power, low cost, and high performance needs for smartphones, tablets, and wearable sensors. The MPU6050 sensor module is a 6-axis motion tracking device featuring 3-axis gyroscope, 3-axis accelerometer, and digital motion processor packed into small container. As an added bonus, it includes an on chip temperature sensor. It uses an I2C bus interface to communicate with the microcontroller [40].

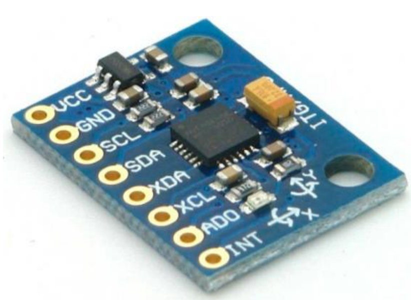

Fig 3.4 MPU 6050 Sensor Module

Table 3.2 MPU6050 Sensor Module Pinout

No	Pin Name	Descriptions
1	INT	Pin for interrupting digital output
2	ADO	LSB Pin for I2C Slave Address. This is the 0th bit of the device's 7-bit slave address. If VCC is connected, the device is read as logic one, and the slave address is changed.
3	XCL	Serial Data Auxiliary Pin. This pin is used to link other I2C enabled sensors to the MPU6050’s SCL pin.
4	XDA	Serial Data Auxiliary Pin. This pin is used to link other I2C enabled sensor to the MPU 6050’SDA pin.
5	SCL	Pin for serial clock. Connect this pin to the SCL pin on the microcontroller
6	SDA	Pin for serial data. Connect this pin to the SDA pin on the microcontroller
7	GND	Pin to the ground. This Pin should be connected to the Ground connector
8	VCC	Pin for power supply. Connect this pin to a +5V DC power source

Table 3.3 MPU6050 sensor module specifications

Parameters and values
Voltage range: 2.3 V to 3.4 V
Consumption : 3.9 mA max
Operating temperature: -40 ^{O}C to 85 ^{O}C
Accelerometer: measuring ranges of 2g,4g,8g, and 16g, with a 3% calibration tolerance
Interface I2C
Temperature sensor built in
Dimensions : 25.5×15.2×2.48 mm
Selectable jumpers on CKL, FSYNC and ADO
Gyroscope with measuring ranges of 250/500/1000/2000 O/sar and a 3 percent calibration tolerance

- **The GPS NEO-6MV2 Module**

When there are a huge number of cows or the farm is large, tracking the whereabouts of cows becomes quite challenging. As a result, each cow will need to be fitted with GPS so that its location can be tracked. GPS transmits a satellite signal that may be processed by a GPS receiver, and the receiver computes position, velocity, and time by emitting the signal. This module determines its location on the globe and returns its longitude and latitude. As a result, the GPS NEO-6MV2 Module has been created to fulfill that role [41].

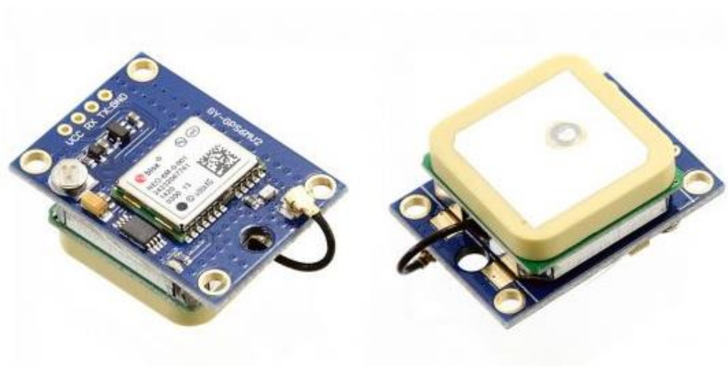

Fig 3.5 GPS NEO-6MV2 Module

- **GPS NEO-6MV2 Specification**

The GPS NEO-6MV2 module is a high performance full GPS receiver with a built in 25×25×4 mm ceramic antenna for reliable satellite search. The power and signal indicators allow you to keep track of the module's status. The module supports baud rates ranging from 4800bps to 230400bps, with 9600 being the default. The NEO-6M chip's operational voltage ranges from 2.7 to 3.6 V. The receiver is 50 channel GPS L1 frequency receiver with a sensitivity of -160 156 dBm. -147 dBm at cold start (without assistance). -161 dBm is used for tracking and navigation [42].

Table 3.4 GPS NEO-6MV2 Pinout descriptions

No	**Name of the pin**	**Pin Description**
1	VCC	Positive supply pin
2	RX	UART Receiver pin
3	TX	Transmit pin for UART
4	GND	Ground

- **GSM Module (SIM800L module)**

A GSM is a type of modem that accepts a SIM card and runs on a mobile operator's subscription, it works in the same way as; it works in the same way as a cellphone. When linked to the Arduino, the GSM modem is utilized to send SMS. GSM delivers a notification to the mobile phone if the values exceed the threshold value.

A GSM/GPRS module can be used to create a real-time cow monitoring device where a short message can be sent to notify the farmer to identify abnormalities leading to the cow's foot and mouth disease with the help of this notification [43].GPRS stands for General Packet Radio Service and it is a technology enhancement for 2G GSM networks that connects your mobile phone to the internet. The original 2G GSM networks were circuit-switched and were not able to provide efficient data services. GPRS added the packet switched part to the GSM networks to enable highly efficient packet-based data services where It is used for enabling mobile data (internet) in 2G GSM mobile networks through packet-switched technology and having the peak download speed of 171.2 kbps which is the maximum.

Fig 3.6 GSM/GPRS Module

Fig 3.7 GSM/GPRS Module Pinout

Table 3.5 SIM800L Module Specification

Features	**Specifications**
Operating frequency	GSM 850MGH, EGSM 900MHZ, DCS 1800MHZ, and PCS 1900MHZ
Operating Voltage rating	3.2V - 4.8V dc
Output Pin Voltage	5V dc
Output Pin Current	25Ma
Communication mode	UART interface, configured for full duplex asynchronous mode
Baud rate	Supports auto bauding, 9.6kb/s used

- **Dallas-18B20 Temperature Sensor**

The DS18B20 sensor is a digital temperature sensor that can measure temperatures between -55^{O}C and + 125 ^{O}C with 5% accuracy. The output resolution ranges from 9 bits to 12 bits for this temperature sensor. It's a programmable digital temperature sensor that converts a 12-bit temperature to a digital word in 750 milliseconds and can be powered via the data line. This sensor can communicate with an inner CPU using a one wire bus protocol, which needs only one data line [44].

Fig 3.8 DS-18B20 Temperature sensor and pinout Symbol

Table 3.6 DS-18B20 Pin Configuration

No	Pin Name	Description
1	Ground	This pin is used to connect the circuit's GND terminal
2	VCC	This pin is used to supply the sensor with power, which might be 3.3V or 5V
3	Data	The temperature value is supplied by the data pin, which can be communicated using the single wire technique.

- **Power Management**

When considering application-based sensors, power management is a major challenge for IoT devices. As a result, it needed to be supplied by small batteries to increase the time it could capture energy utilizing mechanical, thermoelectric, or solar sources. This will be possible because in sleep mode, the device's current requirement decreases, and this factor in sleep mode helps to extend the battery life during power transfer to the devices [45].

3.5.3.2 Software requirements

The minimum software requirements for running a fuzzy logic algorithm for an IoT-based cow health monitoring system for early detection of foot and mouth disease are listed below:

- Windows 10 OS
- Matlab
- Arduino IDE

This part of hardware and software requirements has three main parts such as:

- **Measurement part**: consists of all the tools used in this project including the ATmega328P-UP Microcontroller helps us to program the embedded system, GSM/GPRS module as a Wi-Fi module and sensors for collecting data information.
- **Data Processing**: this part focuses on signals from the inputs (sensors) to the microcontroller at which data will be processed.
- **Cloud storage**: Cloud storage is one way to store data that has been processed by a microcontroller and to go to the cloud using GSM/GPRS module to take it to ThingSpeak cloud storage to be stored and displayed in graphs.

3.6 Process Design

Following the requirements collection and feasibility assessment, the design of the new suggested IoT-based cow health monitoring system for early identification of foot and mouth disease was an important phase.

The design was done after studying the existing schemes and then providing a new scheme that would help me reach my goals. As it was done in chapter 5, this scheme performed better than the existing scheme hence my goal was achieved.

3.7 Conclusion

This chapter includes methods for conducting research, data collection methods, information summaries, their analysis and activities to be undertaken during system design and simulation. Based on this chapter outlining the nature of the project and what it will be used to implement, this project is going to be solved and give a solution to the concerned people. The analysis and design system will be discussed in the following section.

Chapter 4: DESIGN AND ANALYSIS OF THE SYSTEM

4.1 Introduction

A fuzzy logic model is introduced in this chapter to explain the goal of early identification of foot and mouth disease. Many methods have been used in this chapter to give a description and show all the components of a system. This chapter will outline how body temperature and lameness will be controlled by the system and provides measures that are guiding the famers and veterinary doctor.

4.2 System Design Model

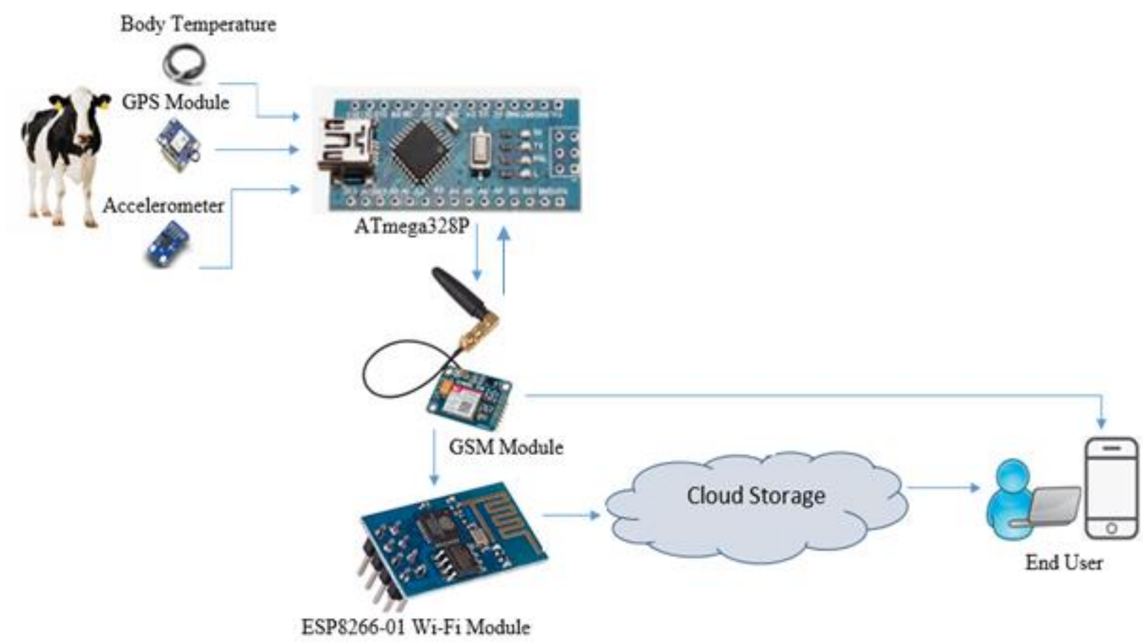

Fig 4.9 System Design Model

Description of the above figure contains all components used to collect data from cow sick's body and veterinary doctor or farmers can monitor the body parameters via IoT cloud platform. Sensors are based on technology where the size and weight must be considered. However, sensors used will be able to detect body temperature, and lameness (footstep) which are playing the important role in treatment and diagnosis of foot and mouth disease. After looking the system model of this project; let us take a look at the levels of body temperature and lameness (footsteps) parameters provided by researchers.

It has been shown that the normal body temperature range for the cow is between 38.5^{o}C and 39.5^{o}C at which case, data are transmitted to the cloud storage.

The farmer or veterinary will suspect that there is anything abnormal for a cow reaching 42^{o}C of body temperature, the range which can cause the serious complicated case and the sudden death. The ranges of body temperature: Low (less than 38^{O}C, at 33^{O}C it leads to death), Normal (38.5^{O}C - 39.5^{O}C) and High (40^{O}C - 42^{O}C) [46].

For the case of footstep (motion), normally each cow averages about 12,000 steps a day but in case of abnormality, it is unwilling to move and stand where it leads to the lying behavior due to the lameness occurred when a cow has a leg or foot pain then a pedometer will record the decrease in a number of steps a cow made in the desired period.

The activity of the cow is described by the numbers of steps done per day where the motion (footstep) with lying behavior indicating lameness (leg or foot pain = lames), no lames (normal movements) (9168 – 12000 steps, fewer lames (fewer movements, irregular stepping) (6090 - 8416 steps) and high lames (lying totally) (277-5520 steps) [47].

4.3 System Analysis

4.3.1 Experimental set up and simulation using Fuzzy logic model

Fuzzy logic is an Artificial Intelligence (AI) approach method for analyzing input variables and imitating human reasoning and cognition information in order to produce the best choice possible given the input. Quantitative analysts can employ fuzzy logic to improve the execution of their algorithms, as it is the most basic sort of analysis. 0 and 1 are extreme situations of truth in Fuzzy logic, however there are several intermediate degrees of truth [48]. This model is appropriate for analyzing body temperature and footstep (motion) parameters in order to warn the farmer or veterinary doctor of aberrant readings because to its low cost, ease of understanding, and great efficiency.

- **Inputs, outputs, and linguistic variables that are fuzzy**

In the proposed fuzzy logic parameter control, two fuzzy input variables, namely cow body temperature and cow motion, are chosen. The output variable that will be delivered to the farmer's phone for notification reasons is the cow body status. The range of numbers that can be utilized to restore the input is shown in Table 1.

Table 4.7 Linguistic variables

Cow body temperature (^{O}C)		Cow motion (Steps)	
Range	**Linguistic variables**	**Range**	**Linguistic variables**
33 - 38 ^{O}C	Low	9168 – 12000 steps	No lames
38.5 - 39.5 ^{O}C	Normal	6090 – 8416 steps	Low lames
40 - 42 ^{O}C	High	277- 5520 steps	High lames

Due to their computational efficiency, triangular fuzzy numbers are frequently employed in a variety of applications. The input and output variables' membership functions are graphically depicted below. The detected motion has three memberships: no lames, low lames, and high lames, and the sensed temperature from the cow's body has three memberships as low, normal and high. Cow body status has a large variety of outputs, which has nine membership functions as indicated in the table below. The membership function of each input and output variable is shown in Table 2.

- **Fuzzy IF- then rules**

1. If (Cow_body_Temperature is Low) and (Cow_motion is No-lames) then (Cow_Body_State is Less-danger) (1)

2. If (Cow_body_Temperature is Low) and (Cow_motion is Low-Lames) then (Cow_Body_State is danger) (1)

3. If (Cow_body_Temperature is Low) and (Cow_motion is High –Lames) then (Cow_body_State is death) (1)

4. If (Cow_body_Temperature is Normal) and (Cow_motion is No-lames) then (Cow_Body_State is normal) (1)

5. If (Cow_body_Temperature is Normal) and (Cow_motion is Low-lames) then (Cow_Body_State is less-foot-pain) (1)

6. If (Cow_body_Temperature is Normal) and (Cow_motion is High-lames) then (Cow_Body_State is foot-pain) (1)

7. If (Cow_body_Temperature is High) and (Cow_motion is No-lames) then (Cow_Body_State is guessing-of-illness) (1)

8. If (Cow_body_Temperature is High) and (Cow_motion is low-lames) then (Cow_Body_State is Guessing_of_FMD) (1)

9. If (Cow_body_Temperature is High) and (Cow_motion is High-lames) then (Cow_Body_State is FMD-Detection) (1)

This research uses the fuzzy logic tool box in MATLAB to create the proposed fuzzy logic control system for temperature, cow motion, and fuzzy rule set in IoT-based cow health monitoring system for early detection of foot and mouth disease: Case of Eastern Province, Rwanda. The graphical user interface is used to create the membership function of input and output variable (Figure 4.10) (GUI).

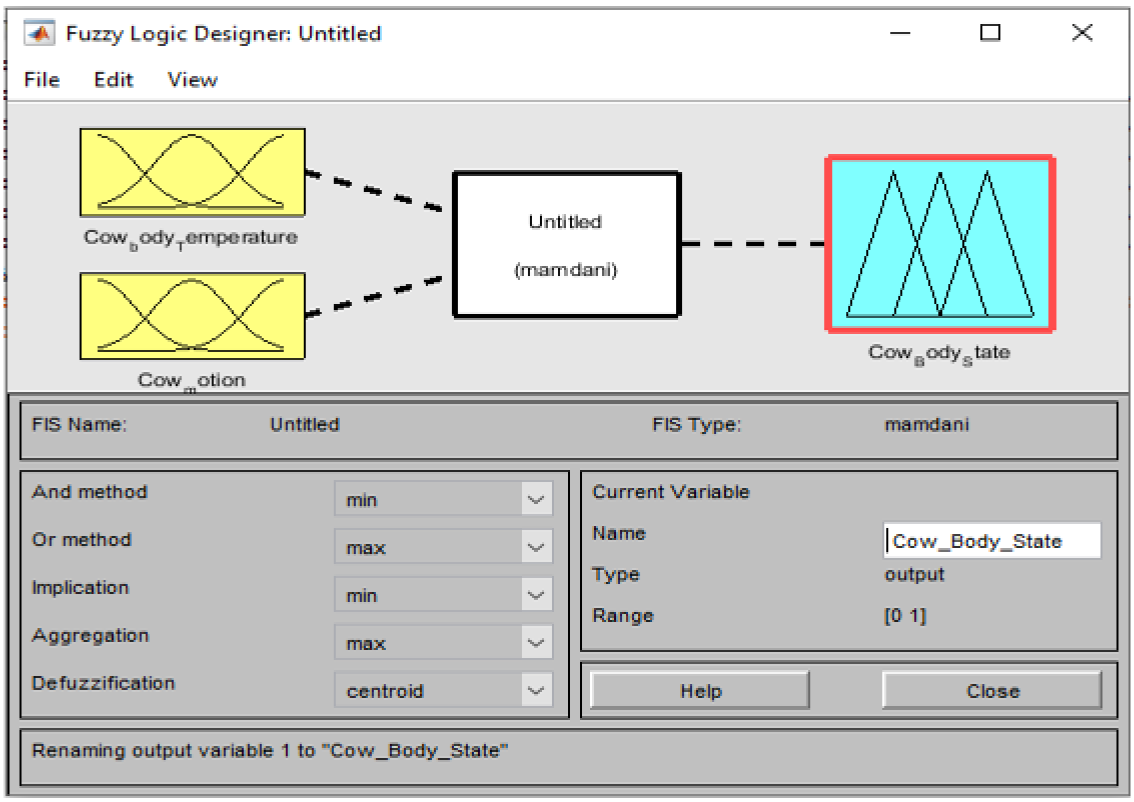

Fig 4.10 Fuzzy inference system editor

The Figure 4.11 illustrates the membership function of cow body temperature which is the input variable. The temperature is considered as low = 33 to 38°C, normal = 38.5 to 39.5°C, and high = 40 to 42°C are the membership function of the cow body temperature.

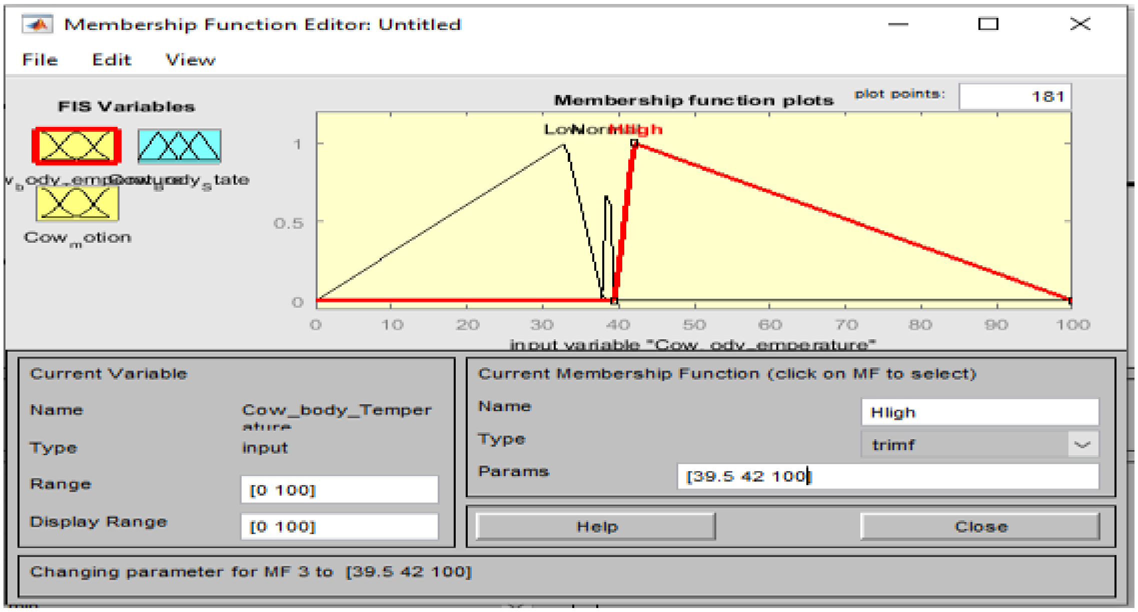

Fig 4.11 Membership function for the cow body temperature

The figure 4.12 elucidates the membership function for inputs variable of cow motion. No lames if = 9168 to 12000 steps, low lames = 6090 to 8416 steps, and high lames = 277 to 5520 steps are the membership functions.

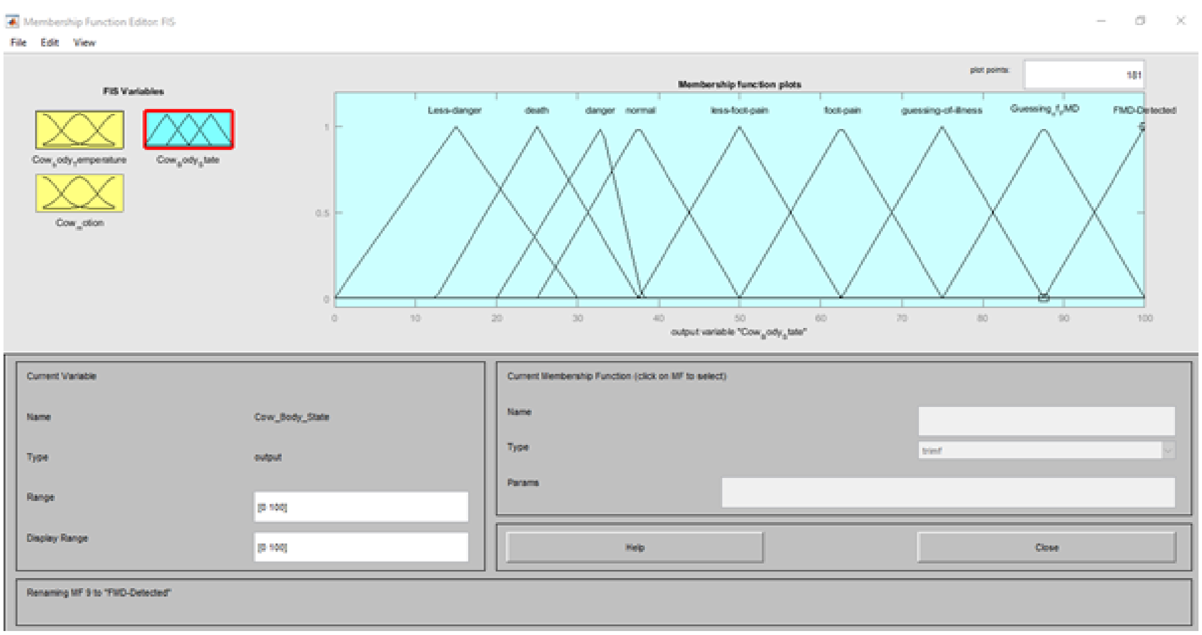

Fig 4.12 Membership function for cow motion (footsteps

The figure 4.13 illuminates the membership function for the output variable of cow body state. It is less danger, danger very danger / death, normal / no danger, less foot pain foot pain, guessing of illness, guessing of FMD, close to the confirmation of FMD (FMD Detected), their range are described in the diagram.

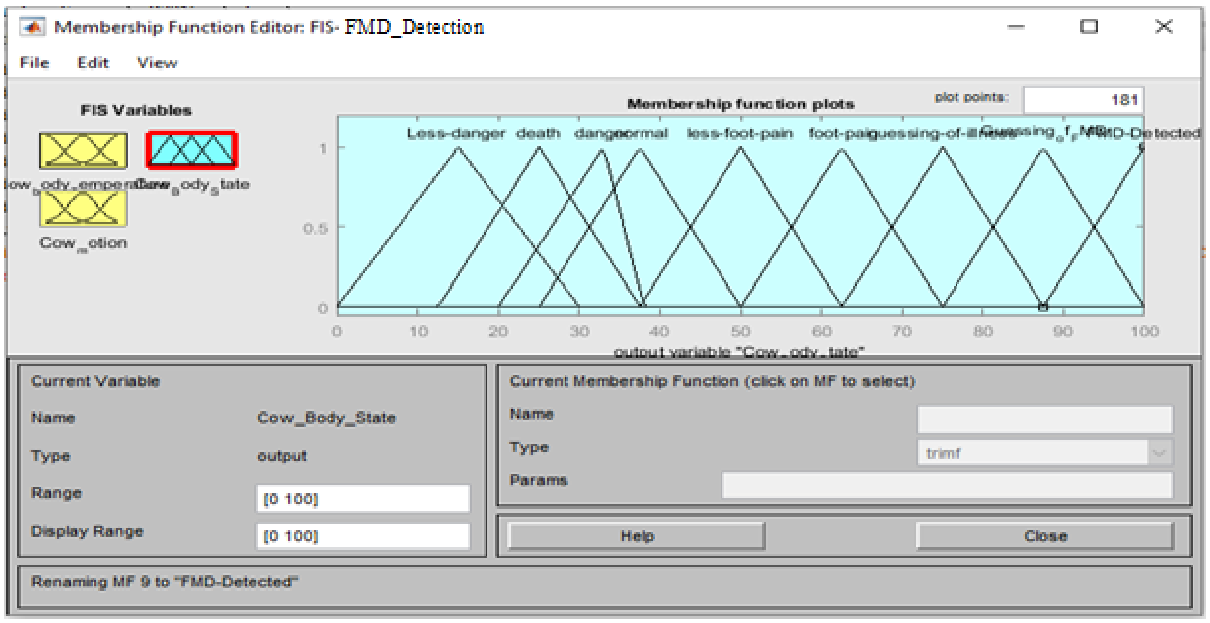

Fig 4.13 Membership function for cow body status

Through MATLAB, using FIS (Fuzzy inference system) editor the suggested fuzzy if-then rules were inserted and it is elucidated in the figure 4.14.

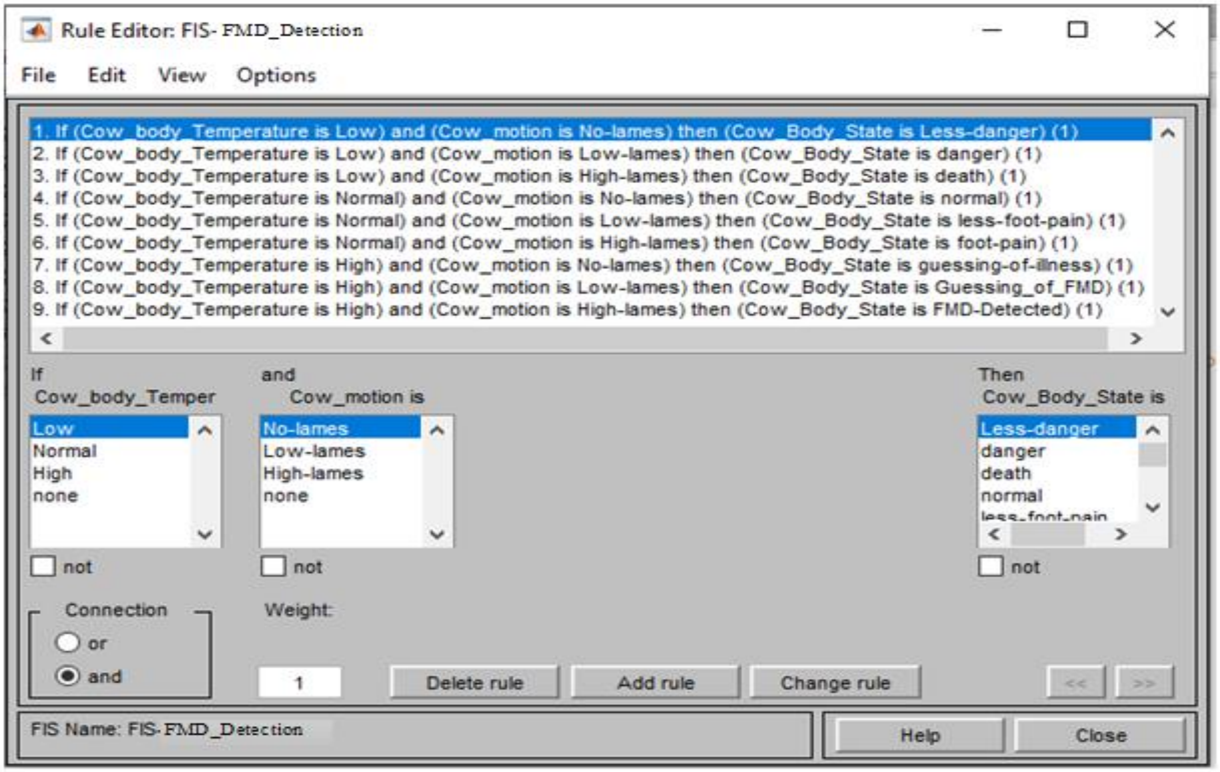

Fig 4.14 Rule editor

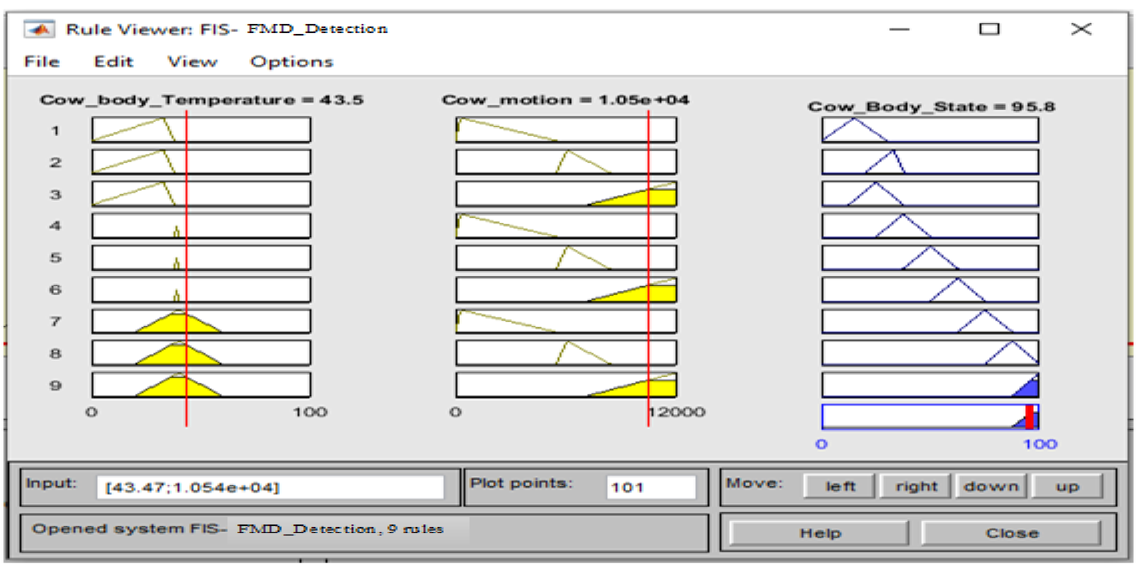

Fig 4.15 Rule view

The suggested control system's surface viewer is shown in the figure 4.16. A three-dimensional output surface is the surface viewer that is used to visualize cow body temperature and movements. The researcher can create different surface viewers for different outputs. When cow body temperature is set to high and cow motion is set to low, the relationship between the input and output variables is shown, and the result reveals that the Cow Body State is detecting of FMD.

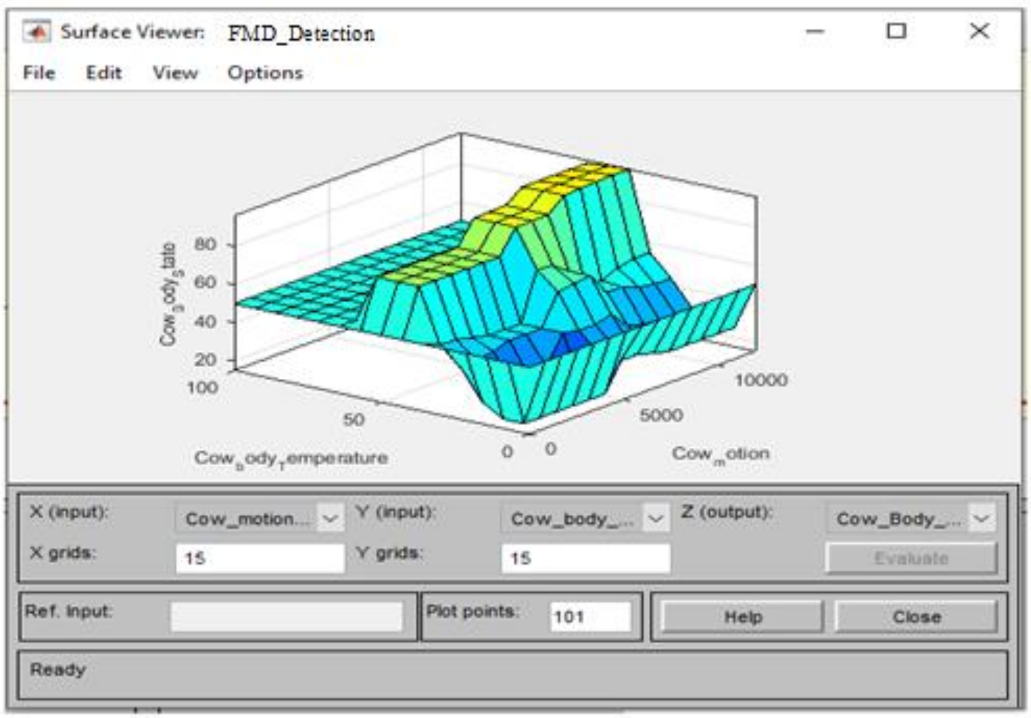

Fig 4.16 Surface Viewer

The control fuzzy logic system is suitable for monitoring cow health and to detect foot and mouth disease by monitoring the lames on the cow's foot using two parameters: body temperature and motion. Fuzzy inputs, body temperature, lames and were evaluated after fuzzy rules built using fuzzy logic tool in MATLAB.

4.4 Activity diagram

Another significant behavioral diagram for demonstrating dynamic system characteristics is the activity diagram. An activity diagram, which is a more detailed variety of a flow chart [49], depicts the flow of information from one action to the next. The flow of activities that occur during the device's communication with the system is depicted in diagram below.

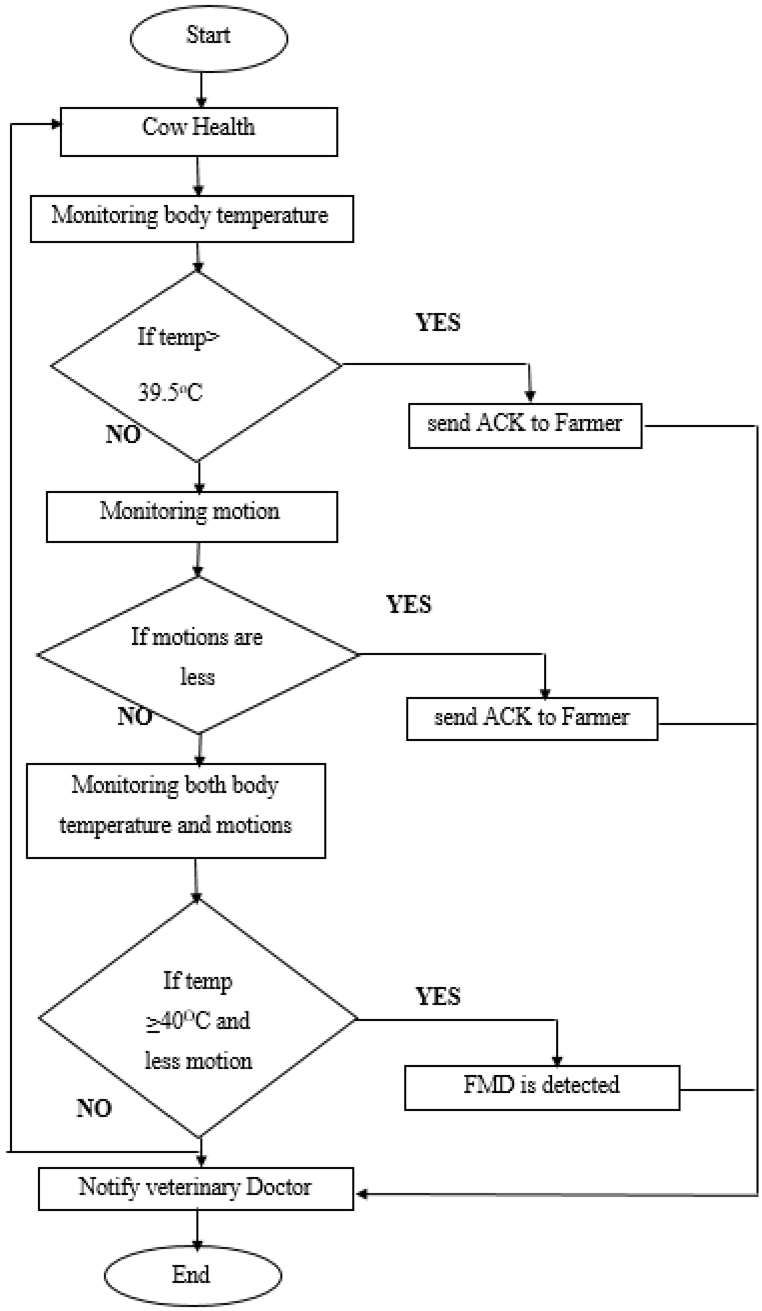

Fig 4.17 System diagram

The fig 4.17 describes how the activity of detecting the FMD is performed where farmer receives the acknowledgement in form of notification when the body temperature is ≥ 39.5 ^{O}C and for less motion to explain that there any abnormal behavior due to the increment of body temperature and activity related to the motion. FMD is detected at the body temperature below of 40^{O}C where veterinary doctor is notified for taking decision at real time.

4.5 System Architecture

The system architecture is a conceptual model that defines a structure of a system, behavior and additional views [50]. An overview of equipment utilized in this project is provided by the IoT-based cow health monitoring system for early detection of foot and mouth disease.

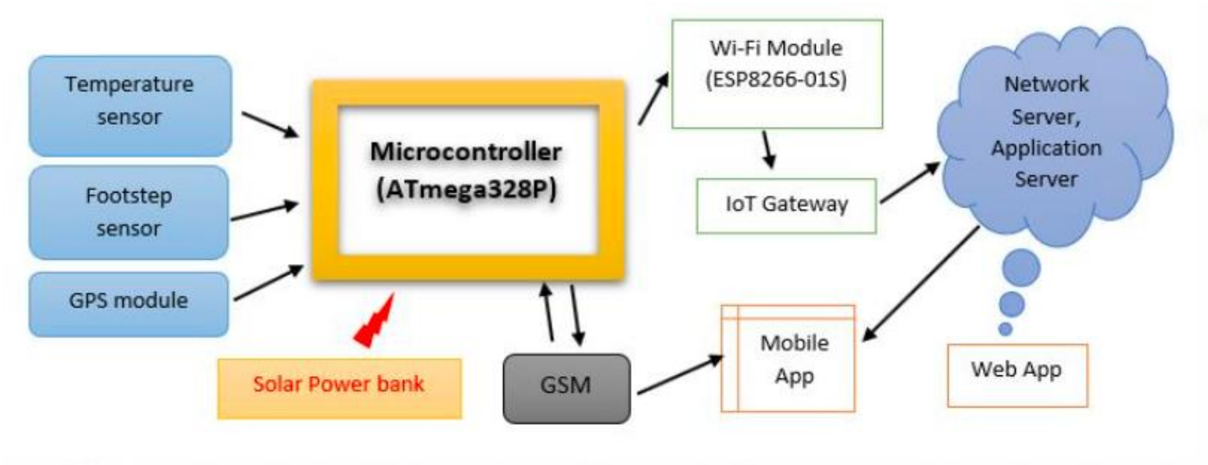

Fig 4.18 System Architecture

This designed system will provide a solution that data are collected from cow sick's body and veterinary doctors or farmers can monitor the body parameters via IoT cloud platform. Technology underpins the utilization of sensors where the size and weight must be considered. However, sensors will be used for gathering data of body temperature, and lameness (motion changes) which are playing the important role in treatment and in diagnosis of foot and mouth disease. The body temperature sensor Dallas1-18B20 which senses temperature on cow body instead of using the rectal thermometer. MPU 6050 Gyro-accelerometer will be used for giving the insight about a decrease in number of steps with the time which lead to the cow motions (lying time, and walking based on footsteps done) as a decrease of footstep numbers that a cow can walk per day, can be used as a tool for lameness detection and detector of time for a disease. The Neo 6M GPS module is used for locating the sick cow, while the GSM module (SIM800L) is used to send an SMS to the farmer and veterinarian when any abnormalities are detected that could lead to Foot and Mouth Disease, and it supports a quad-band GSM/GPRS network that allows it to work almost anywhere in the world. The ATmega328P microcontroller will monitor and control sensor data before sending it to the cloud via the Wi-Fi module.

4.6 Circuit diagram

An electrical circuit using any simple component, image or standard symbols corresponds to a circuit diagram [51]. In addition, it shows how all devices work together to create a single solution for foot and mouth disease, which is the goal of the project.

Fig 4.19 Circuit Diagram

Chapter 5: RESULTS AND DISCUSSION

5.1 Results

5.1.1 Introduction

In this chapter, the researcher evaluates the effectiveness of the IoT-based cattle health monitoring system to quickly diagnose foot and mouth disease; and looked at how temperatures and graphical measures have evolved over time, how cloud storage holds data and how a cow's health status can be obtained when is healthy or unhealthy. This chapter also outlines the codes used to enable the system to provide solutions based on what is shown in this project.

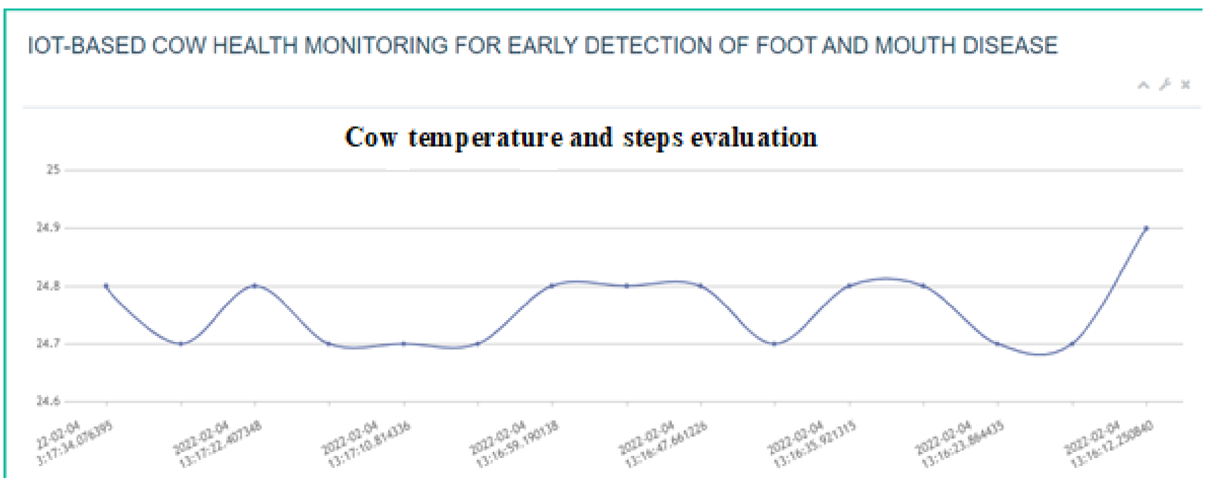

Fig 5.20 Evaluation of body temperature and steps

This chapter shows measures used in graphs and codes, where the researcher showed that the body temperature between 38.5^{O}C and 39.5^{O}C is normal. But as long as the body temperature exceeds the range of 40^{O}C and 42^{O}C the cow will show the abnormalities cases. These criteria are what the researcher has been used to get the result but the system shows how the wearable device that are going to be different in the notification message. The description of this graph is when the body temperature is going beyond the normal range and the time of resting for a cow increases where this leads to the critical of steps done in an instant of time and then the output will appear in a discrete number of temperature and steps. All the result will see in the cloud storage where data are stored. This graph shows normal and abnormal ranges as it is given.

5.1.2 Evaluation of notification message of body temperature with GPS coordinates

In notification process, the farmer or veterinary doctor receives an alert message showing the necessary information about the cow manifesting the high temperature, its location and identity. For this case, he can access the cloud storage to see all details including the number of steps done.

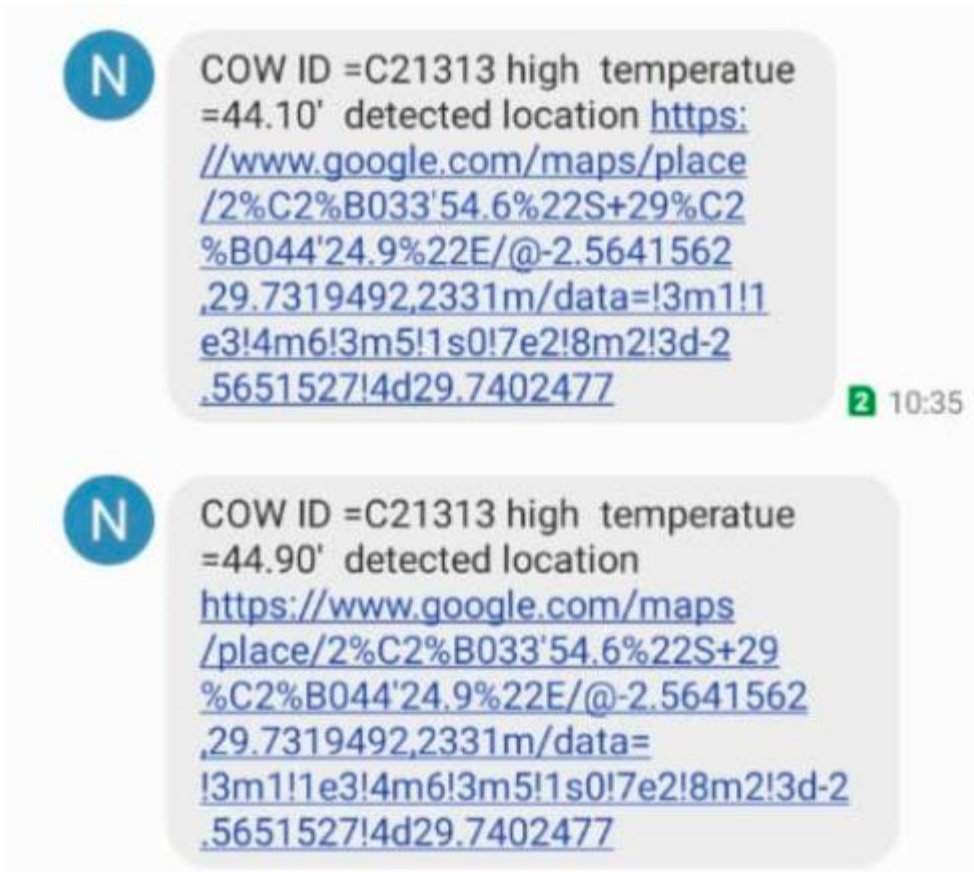

Fig 5.21 Notification message with GPS coordinates

As it is shown in notification message, the farmer or veterinary doctor will receive the alert, when the body temperature exceeds the normal range and the cow manifesting the abnormal state will be localized using GPS module.

5.1.3 Evaluation of body temperature and steps when in database

##	Temperature	Comment	Motions Steps	COW_ID	LOCATION	Due Time
123	40.50 °C	HIGH TEMPERATURE	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:30:0
124	40.20 °C	HIGH TEMPERATURE	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:30:0
125	39.80 °C	HIGH TEMPERATURE	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:29:5
126	39.50 °C	Normal	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:29:5
127	39.10 °C	Normal	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:29:4
128	38.80 °C	Normal	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:29:3
129	38.50 °C	Normal	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:29:3
130	38.00 °C	LOW TEMPERATURE	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:29:2
131	37.80 °C	LOW TEMPERATURE	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:29:1
132	37.50 °C	LOW TEMPERATURE	ABNORMAL Steps	C21313	-2.565153, 29.740248	2022-02-04 12:29:0

Fig 5. 22 Evaluation of body temperature and steps in database.

5.2 Discussion

A warning system that alerts veterinary doctors and farmers on foot and mouth disease can contribute to early detection of health issues that may arise such as high cow's body temperature or lameness. Many studies have been done out in the subject of recognizing foot and mouth illness to identify cow behavior by building systems. Many of these systems, however, are only capable of distinguishing between one or two parameters (K. B. Swain and S. Mahato, December 2018).

The IoT based system for monitoring cow health contributes to early detection of foot and mouth disease contribute to accurate monitoring and classifying different stages of behavior through measuring both body temperature and lameness parameters. It can provide useful assistance to assess cow health and well-being which is the subject of this research. Compared to the risk factors for the invasion, spread, and persistence of foot and mouth disease in East Rwanda. (J.C. Udahemuka and G.O. Aboge, 2020), the wearable device with body temperature and motion (footstep) sensors with GSM/GPRS module has the advantage of instantaneous monitoring of body temperature and movement data capture.

Furthermore, the system operates at 20 MHz and consumes less power than some 2.4 GHz detection systems for Cattle Health Management (Pravinthraja, A. B. S, and M. Nandhini,2020), and it may be used on big farms. Currently, the proposed system only collects elevated body temperatures and lameness that lead to FMD. In this research, the non-standalone system is used where the veterinary doctor or the farmer will receive the notification without the necessity of the internet connection. And then the disease will be monitored accuracy at real time.

Chapter 6: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The present study uses sensors such as a body temperature sensor, a motion sensor (accelerometer), an ATmega328P microcontroller, and mobile devices to monitor the health of cows for a quick diagnosis of mouth and foot diseases. The used technique helps to track the changes in a cow's body temperature and footstep as well as the measures taken for detecting mouth and foot diseases. The researcher recommends that an IoT-based system to monitor cow's health for early detection of mouth and foot diseases to be fitted around the cow's neck to collect parameters that will help farmers monitor the cow's health. If any anomalies are discovered in the cow, the farmer or veterinarian will be contacted by SMS. The data collected from the numerous sensors is constantly monitored on the internet. As a result, tracking the whereabouts of cows takes time and is challenging. The suggested approach allows the health status of the cows to be tracked without the involvement of humans. Medicines can be taken swiftly if there is any anomaly in the health status of the cow. Thus, this system is very suitable for the farmers or veterinary doctors to control the cows caring for the condition and take the decision in real-time.

6.2 Recommendation

These days, technology is accelerating and bringing innovations. This project will need to be expanded according to other challenges that will emerge. This project does not meet all the requirements for monitoring the detection of mouth and foot diseases due to the short duration and lack of some equipment. This project will be extended to generate data for early detection of mouth and food diseases, how to send an alert message to the farmer or veterinary doctor via GSM communication, properly combining the abnormalities of more than one parameters and the notification message when the system is turned off where it can be disconnected to power by users or other things.

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