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Fuzzy Logic Applied to Smart Cow's Wearable Device for Early Detection of Foot and Mouth Disease in Rwanda

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Abstract:- Nowadays, the 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 detection 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. The IoT based cow health monitoring system monitors various cow health parameters such as body temperature, lameness and location of cows. In this system, 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 the veterinary doctor and farmer when abnormal values are leading to the foot and mouth disease early and prevent its spread. The results can be viewed in internet on interfacing ESP8266 Wi-Fi module and in mobile application to provide full information and treatments at real time in which will show the live updates.

Keywords:- *Internet of Things, Atmega328p, Wi-Fi Module, Sensors, Cow's Health Monitoring, Fuzzy Inference System, Foot and Mouth Disease, GSM, Cloud Storage.*

I. INTRODUCTION

The Rwanda as one country of Africa, livestock production has played a most important part in the development[1], where currently livestock production is some of the fastest growing agricultural subsectors in Rwanda and plays an important role in life of Rwandans. Farmers in Rwanda are facing very serious challenges like diseases such as foot and mouth disease, mastitis bacterial disease and worms infectious viral that affect cows in the farm and cause poor production of milk, particularly foot and mouth disease is significant challenge to the cattle subsector in Rwanda in several parts of Eastern Province [2]. The way of monitoring them, is also becoming difficult, day to day where employees do not have the time to observe cow to cow and detect symptoms of foot and mouth disease. Farmers with the help of Government of Rwanda, must solve these challenges, in this work, we propose an Internet of Things(IoT) based cow health monitoring system for early detection of foot and mouth disease. Sensors are connected together to form a wearable device of a cow to monitor the body temperature and lameness (footstep) of each cow. Normally, the body temperature of cow is between 38.5^{o}C and 39.5^{o}C while for footstep (motion), normally each cow averages about 12,000 steps a day [3][4]. If the body temperature is reaching 42^{O}C and the lameness become more frequently (less than 6090 steps), it is notified to the farmer that foot and mouth disease is detected via SMS through GSM modem[5]. It is very challenging to find the location of cows when there are a huge number of cows in large sized farm. So, it will be necessary to fit each cow with GPS which helps to track its location at real time when foot and mouth disease detection is manifested [6]. In this system, the ATmega328P microcontroller receives the data from the sensors for processing it accordingly and the ESP8266-01 Wi-Fi module will transfer the data internet, so the cow can be monitored from outside the farm.

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II. BACKGROUND AND MOTIVATION

Foot and Mouth Disease (FMD) is a highly contagious viral disease caused by a picornavirus known as Foot Mouth Disease Virus (FMDV) [7].The Eastern Province of Rwanda is the largest province having 9813 km^2 occupied with a predominant farming system where livestock population is composed of approximately 500,000 cows, 500,000 goats, 13,000 sheep and 130,000 pigs[8].This province is very affected by the foot and mouth disease especially in the dry season as the period during which FDM outbreaks are more likely to occur. Foot and mouth disease affects the production of milk which is cause the negative results for farmers in the livestock domain. Monitoring cow health and predicting the exact type of disease is difficult for them, therefore the disease can be predicted after monitoring some vital signs like body temperature as an important physiological parameter and inductive of the health dairy [9] 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 [10], 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.

III. RELATED WORKS

There were several interesting researches about cattle health monitoring dealing with controlling cattle in large farms using Internet of Things to provide immediately the change on cattle health condition in real time.

A. Kumar Suresh K. proposed in their work the system [11] based on monitoring the health conditions of the cattle 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).

B. Shivank Vyas, Shukla Vipin, and Nishant Doshi in their system [12], simply monitoring more parameters considered to allow the prior detection of possible disease. In this research paper, a system is developed for early detection of Foot and Mouth Disease (FMD) and Mastitis disease in cow using Internet of Things (IoT), different sensors and Machine Learning Algorithm (Neural Networks), for temperature, sound and motion.

C. Chen Pei [13] proposed the system for the cow estrus detection based on Narrow Band Internet of Things (NB-IoT) communication by examine the physical status of the cow such as temperature which will change significantly during their estrus, and transmit the data using parameters such as temperature, humidity and heartbeat.

D. K. Shah, K. Shah, B. Thakkar, and M. Hetal Amrutia [14], also explained the Internet of Things technology for farmers using sensors to collect transfer it to the Arduino Uno. Through the computer monitor, all hardware components and sensors will read the results and track the current status and location of the livestock using the global positioning system (GPS).

E. S. Shetty, P.K, A.K gave an explanation in their work [15], about 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.

In these researches, it has identified a serious defiiciency of analytics and intelligence in previously proposed systems and this is leading to the gaps between the desired necessity of the system and the proposed solution, where they used to grant the network connectivity but do not consider the real time analytics. They follow the technique to process and analyze previously collected data and perform offline analysis, which is not suitable 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 and taking decision anywhere and anytime based on the analysis of collected data and the detection of the disease related to the vital signs or cow behavior.

IV. PROPOSED METHODOLOGY

The data information to be used are cow's health parameters like body temperature and lameness(footstep) relationship for cow's health. The environmental data regarding the temperature and lameness will be collected from the body's cow. The collection of data will allow the farmers to have full control to their cows. Data collection tools will be used such as interview and documentation.

Data analysis will be performed using Fuzzy Logic Model (Artificial Intelligent), Statistical Package for the Social Sciences (SPSS) and MATLAB software to provide statistical analysis.

A. System Architecture

The following figure, illustrates the system approach design of the proposed solution to the problem.

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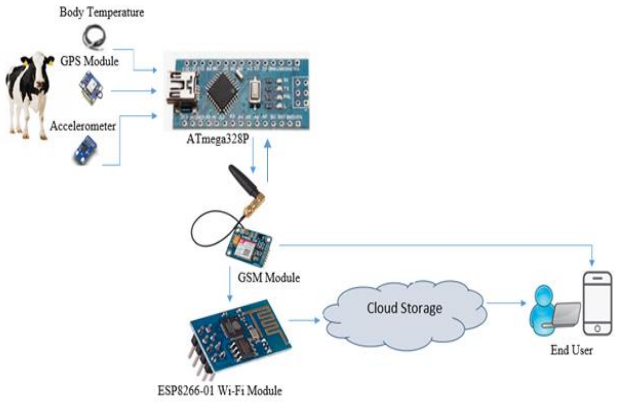

Fig.1. Architectural Design of the proposed system

B. The system consists of several components

- ATmeg328P
- DS-18B20 Temperature sensor
- GSM Module (SIM800L Module**)**
- GPS NEO-6MV2 Module
- ESP 8266-01 Wi-Fi module
- ADXL 335 Accelerometer sensor

ATmega328P is one of the high performances Automatic Voltage Regulator (AVR) technology microcontroller with a big number of pins and attributes. It is designed by 8-bit Complementary Metal-Oxide Semiconductor (CMOS) technology and a type of microprocessor architecture known as RSIC CPU which improve its performance. Its power efficiency is improved by auto sleeps and interior temperature sensor. This ATmega328 Integrated Circuit is characterized by inner protections and numerous programming methods helping the engineers to control different circumstances increasing every day[16].

This development board is used to collect data from sensors and process them to create cases which trigger different functions.

Fig.2. ATmega328P IC

Dallas-18B20 Temperature sensor (DS18B20 sensor) is digital temperature sensor used to measure temperature in range of -55^{O}C to + 125^{O}C with ±5% accuracy. This temperature sensor supplies 9-bit to 12-bit readings as the range of output resolution. It is programmable and digital temperature sensor where it changes the 12-bit temperature to digital word within 750 ms time and can be power driven from the data line. The communication of this sensor can be done through a one wire bus protocol which uses one data line to communicate with an inner microprocessor[17]. The DS-18B20 is suitable to monitor body temperature of the cow where it is able to show that the temperature is normal or not.

Fig.3. DS-18B20 Temperature sensor

GSM Module (SIM800L Module) is actually a modem which accepts a SIM card and operates over a subscription to mobile operator, it is operated just like mobile phone. The GSM modem sends a SMS when connected to the Arduino. If the values are beyond to the threshold value GSM sends a notification to mobile phone. The farmer can identify abnormalities leading to the foot and mouth disease of the cow with the help this notification [5].The GSM enables to send SMS to the farmer or veterinary doctor at any critical situations.

Fig.4. SIM800L Module

GPS NEO-6MV2 Module: The GPS NEO-6MV2 is well-performing complete GPS receiver with a built-in 25 x 25 x 4mm ceramic antenna, which provides a strong satellite search capability. With the power and signal indicators, you can monitor the functionality of the module. The supported baud rate of the module is from 4800bps to 230400bps with default baud of 9600 and its operated voltage is from 2.7 to 3.6Volts. The receiver type is 50 channels GPS L1 frequency with the sensitivity (dBm) of -160 156 Cold Start (without aiding) is -147 dBm Tracking and Navigation is -161 dBm [11].This GPS module helps in tracking the cow and also transmits the data wirelessly to the cloud.

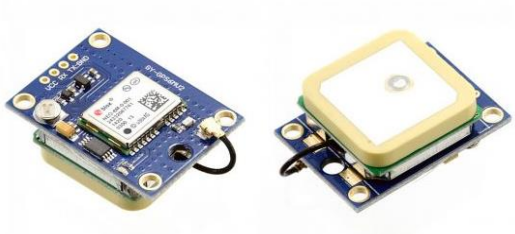

Fig.5. GPS NEO-6MV2 Module

ESP 8266-01 Wi-Fi module is Wi-Fi module really useful, cheap for controlling devices over the Internet. It allows Microcontroller easily access to Wi-Fi network as it is the primarily incorporated Wi-Fi chip in the industry domain where it is capable of assimilating the antenna switches,

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radiofrequency, power amplifier, low nose receiver amplifier, and power executive elements [18]. It is less complicated why it is used to monitor health of many cattle at real time.

Fig.6. Wi-Fi Module

ADXL 335 Accelerometer sensor: A type of motion sensor, small size, with low power consumption and having a complete 3-axis accelerometer with trained voltage outputs. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration [19]. These sensors are used with the aim of monitoring the behavior of cow for improving animal's health.

Fig.7. ADXL 335 Accelerometer

V. RESULTS AND DISCUSSION

A. Experimental set up and simulation using Fuzzy logic model

The fuzzy logic model is an approach method of Artificial Intelligence (AI) used to analyze input variable and imitate human reasoning and cognition information and making the best possible decision given by the input. Fuzzy logic can be used by quantitative analysts to improve the execution of their algorithms where it is most basic type of analysis. The Fuzzy logic includes zero (0) and one (1) as exciting cases of reality but with various intermediate degrees of truth[20].

Due to its low cost, easy to understand and high efficiency, this model is suitable to analyze the body temperature and footstep (motion) parameters of the cow for notifying the abnormal values to farmer or veterinary doctor.

B. Fuzzy inputs, output and their linguistic variables

In the proposed fuzzy logic parameter control 3 fuzzy input variables are chosen namely, body temperature and motion. The cow body state is the output variable which will be transmitted to farmer owner' mobile phone for notification. The following table 1 provides ranges with values for fixing the input.

Table I. Fuzzy Inputs, Output And Their 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

C. 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)

In this research paper, fuzzy logic tool box in MATLAB is used to implement the proposed fuzzy logic control system for temperature (cow's body), cow motion in IoT Based Cow Health Monitoring System for Early Detection of Foot and Mouth Disease: Case of Eastern Province, Rwanda and fuzzy rule set. Using the graphical user interface (GUI), the membership function of input and output variables (Fig. 8) are designed as follows:

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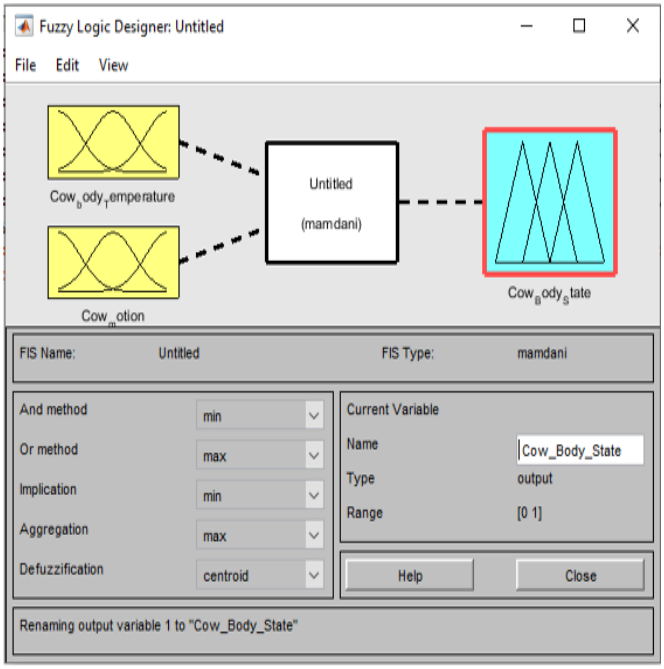

Fig. 8. Fuzzy inference system editor

Fig. 9 shows the membership function for the input variable cow body temperature. The membership function for body_ temperature, low = 33 to 38, normal = 38.5 to 39.5 and high = 40 to 42^{O}C.

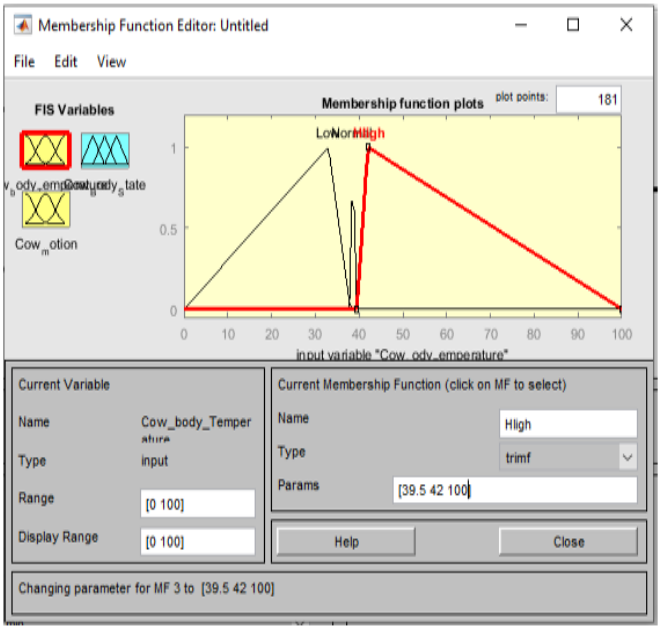

Fig. 9. Membership function for cow body temperature

Fig. 10 shows membership function for the input variable cow motion. Membership function for no lames= 9168 to 12000 steps, low lames = 6090 to 8416 steps and high lames = 277 to 5520 steps.

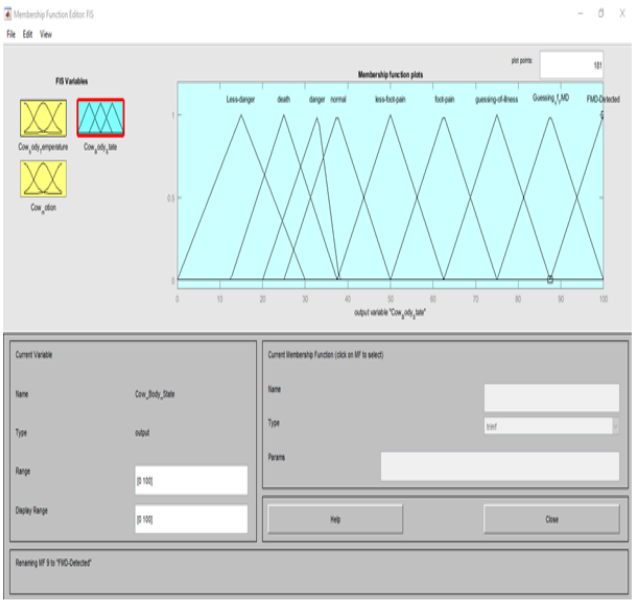

Fig. 10. Membership function for cow motion

Fig. 11 shows the membership function for the output variable cow body state. The membership function 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 Detection), their ranges are defined in the diagram below.

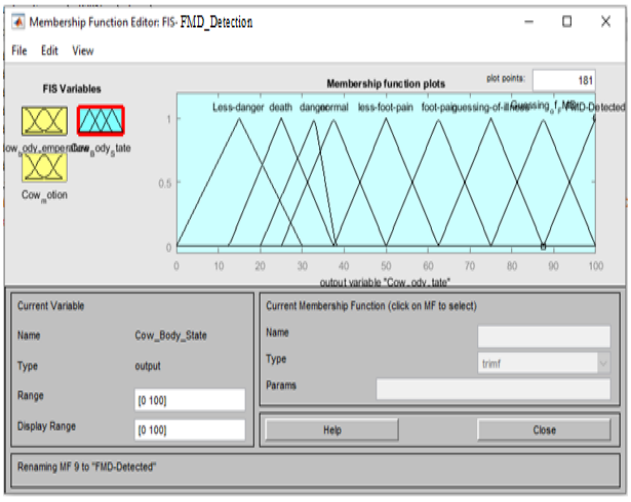

Fig. 11. Membership function for cow body status

Using FIS (Fuzzy inference system) editor in MATLAB the proposed fuzzy if-then rules are inserted as it is shown in the Fig. 12.

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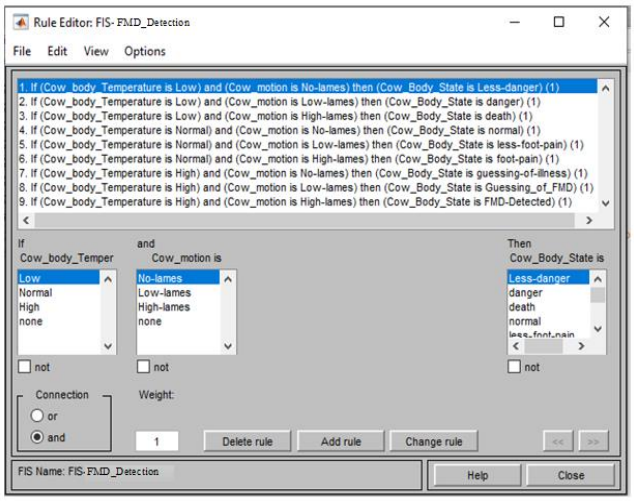

Fig. 12. Rule editor

Fig. 13 illustrates the rules view that show the simulation of combined all input and output membership functions.

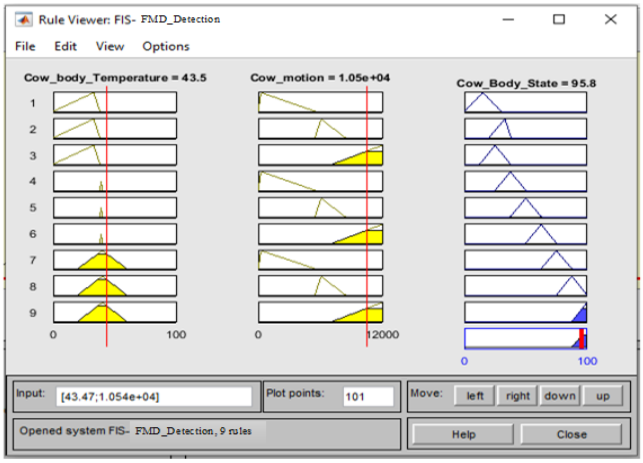

Fig. 13. Rule view

Fig. 14 illustrates the surface viewer of the suggested control system. The surface viewer is a 3-Dimensional output surface, here drawn for cow body temperature and cow motion. For varying output, I can generate different surface viewer.

This shows the relationship among the input variables and the output variables when body temperature is set to high and motion is set to low and the result is showing that the Cow_Body_State is the Detection_of_FMD.

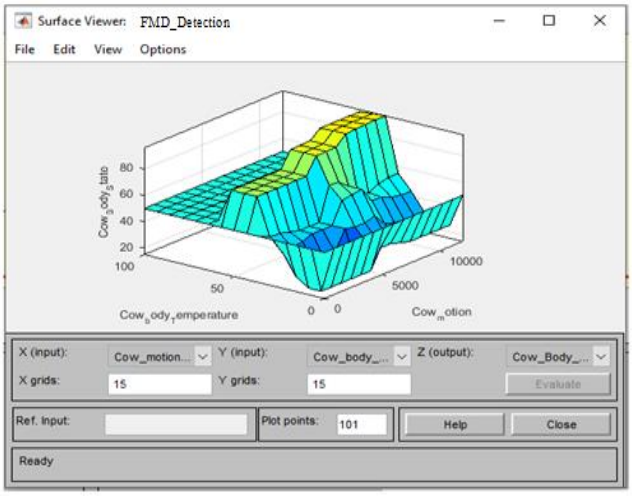

Fig. 14. Surface Viewer

The fuzzy logic control system is used to provide the suitability monitor of cow health and to detect the foot and mouth disease using two parameters, body temperature and motion by monitoring the lames appeared on the cow's foot. Fuzzy inputs, body temperature, lames and fuzzy rules have been structured by using fuzzy logic tool in mat lab, the parameter has been estimated.

VI. DISCUSSION

The early detection of foot and mouth disease can be applied as the input to warning systems which alert the veterinary doctor or the farmer when some abnormal health cases occurred like high body temperature and lameness. Many studies have carried out to identify cow behavior by developing systems in the field of recognize foot and mouth disease. However, many of these systems are suited to distinguish only one or two parameters (K. B. Swain and S. Mahato, December 2018). In this research project, the application of an IoT-based cow health monitoring system for early detection of foot and mouth disease to accurately monitor and classify nine categories of behavior by measuring both body temperature and lameness parameters where it can provide a useful help to assess cow health and wellbeing. The wearable device with body temperature and motion (footstep) sensors with GSM/GPRS module Compared with Risk factors for the incursion, spread and persistence of the foot and mouth disease virus in Eastern Rwanda(J. C. Udahemuka, G. O. Aboge, 2020), has the advantage of real-time monitoring the body temperature and movement data acquisition. Moreover, the system working at 20 MHz with lower power consumption comparing with some 2.4 GHz detection system for Cattle Health Management (Pravinthraja, A. B. S, and M. Nandhini,2020) and it is applicable on the large scale of farms. At present, the proposed system has only gathered the abnormal body temperature and lameness leading to the 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

VII. CONCLUSION

This research presents a cow's health monitoring for early detection of foot and mouth disease consisting of sensors namely the body temperature sensor, motion sensor (accelerometer), as well as ATmega328P microcontroller and mobile devices are also used. This system is used to monitor the variation condition of cow's body temperature and the footsteps done where foot and mouth disease detection will be monitored. The researcher proposes that IoT based Cow health monitoring system for early detection of toot and mouth disease should be installed the neck of the cow to collect parameters which shall then facilitate farmers in monitoring the cow health. If any abnormalities found in the cow, it will be notified to the farmer or veterinarian via SMS. The values got from the various sensors are been continuously monitored in the internet. Hence it is time consuming and is also difficult to track the location of animals. In the proposed system, without human involvement health status of the animals can be monitored. If there is any abnormality in the health condition of cow medicines can be taken quickly. 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.

VIII. RECOMMENDATIONS

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 foot and mouth disease due to the short duration and lack of some equipment. This project will be extended to early detection of foot and mouth disease, 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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