



**AFRICAN CENTER OF EXCELLENCE
IN
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Research Title: IoT Based Gorilla Monitoring System in Rwanda

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December, 2020

Bonafide Certificate

This is to certify that this submitted Research Thesis work report is a record of the original work done by **NIYIGENA Jerome (REF.NO: 215041434)**, MSc. IoT-WISNET Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things. Certified further, that according to the best of my knowledge; the work reported here doesn't form a part of any other research work.

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Declaration

I NIYIGENA Jerome, Master 'student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis is my own original work and it has never been presented before anywhere in the world.

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Date: 24./12./2020

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Abstract

Rwanda is an African country that has many mountains covered by forests. These forests are friendly homes to different animal's species that make them a favorite environment for tourists. The most attractive geographical ecosystem is Rwanda's national volcano park(NVP) forest, the place where mountain gorillas are located. Gorillas are among the animals that are mostly visited by tourists in Rwanda, and they are moving inside the large forest looking where there is enough food. These displacements in such an environment complicate the guards and tourists to located them easily. In this research thesis, we provide a solution to determine the gorillas' location in real-time using Internet of Things (IoT) technology. The resources used include various sensors, Arduino microcontroller, ESP8266 module and communication protocols such as MQTT. Gorillas can be detected using different parameters such as their colors and height among others.

Keywords: Gorilla, IoT, MQTT, gorilla detection

List of Acronyms

ACEIoT= African Center of Excellence in Internet of things

GMS: Gorilla monitoring system

IoT= Internet of things

IoTGMS: Internet of thing based gorilla monitoring system

IT: Information Technology

ICT: Information Communication Technology

LAN: Local Area Network

MQTT: Message Queuing Telemetry Transport

ORTPN: Rwandan Office of Tourism and National Parks

RDB= Rwanda Development Board

PIR: Passive infrared sensor

SAD: System Analysis and design

SoC: System on Chip

VNP: Volcanoes National Park

WAN= Wide area network

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CHAPTER I: GENERAL INTRODUCTION

1.1 Introduction

Rwanda is making great strides in technology and industry like other countries, the development of industries causes the atmosphere to be contaminated and causing various health problems to the living things, therefore different species extinct on Earth, including these gorillas that are endangered animals. International Gorilla Conservation Program together with the African Wildlife foundation they started the way for conserving climate change and reduce the risk of mountain gorillas from losing their life [1]. the Figure 2 illustrate the level of how number of tourists increased Since 2008, their number was increased to 17,000 most of them are interested to visit Volcanoes National Park, for that reason why Rwanda considers this park as a tool for supporting various activities in the park and lifting the poor out of poverty in Rwanda, as seen on Figure 1 , 5% park revenues from tourism are used to support community projects to improve their standards of living [2].

The gorillas are the most visited animals in Rwanda, and they live in volcanoes National parks. When we look back at the characteristics of these animals we see a lot similarities related to humans. These include the face, teeth, feet and their behavior in families and much more. All of this and more that we have not mentioned play an important role in attracting tourists

The gorilla's teeth are 32, with large teeth just like a human and the gorilla has chains around their eyes. A gorilla has a human mind that includes things like hearing, seeing, breathing, knowing the taste of something, and treating people as they are [3].

The gorillas' animals are endangered so they should be taken care of them so that they do not disappear from the world, and they have more similarities to human beings. Gorillas mammals give milk drink to their children, have birth as women do and they have different families where each family member has its representative. Dian Fossey, a botanist who conducted the karisoke research in 1967 she describes endangered species whose similarities are a lot closer to humans including its genome [4]. The team of biologist and zoologist from Cambridge alumni Gregory

Jordan in their research they found that human, Gorilla, and chimpanzees are close to human genetically, according to the 15% of the human genome are similar to the gorillas [5].

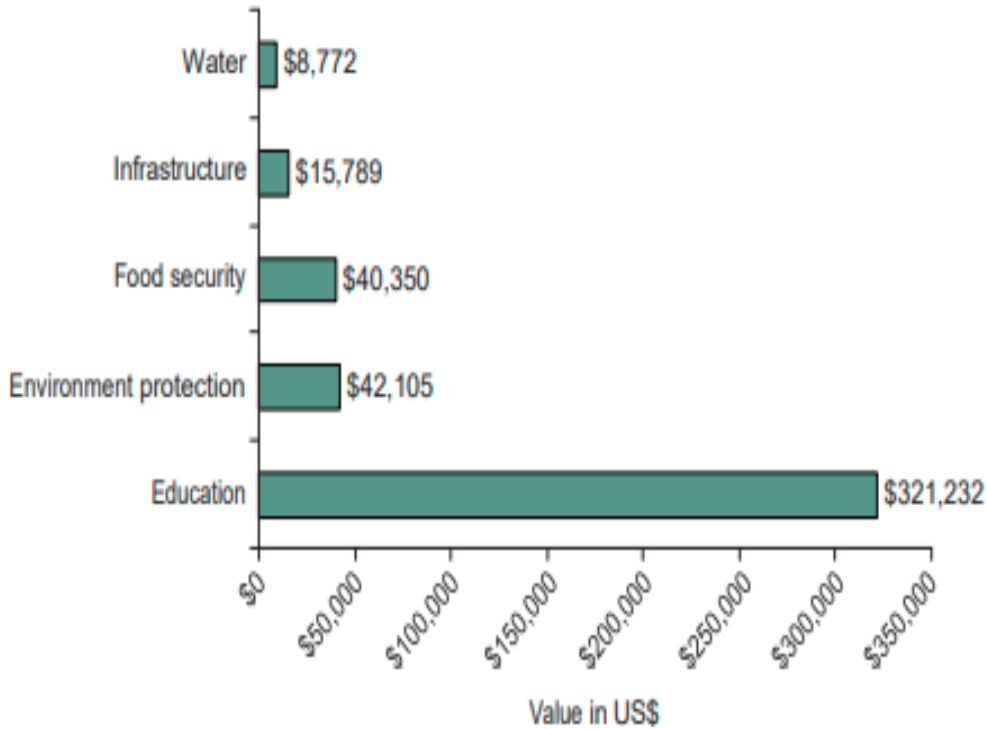


Figure 1: Funds disbursed to community project around [1]

IoT based monitoring system used to ensure the management of gorillas and detecting their presence inside Volcanoes National Park in Rwanda.

Rwanda's gorillas have been visited by many foreign like Bill Gates, Natalie Portman, and Ted Turner, and others during the annual gorilla naming ceremony. The number of tourists visiting gorillas has increased over the years, they have come to visit gorillas and learn about the country's culture, leaving behind funds that will be used to improve the park conservation and improve the livelihoods of the people [2].

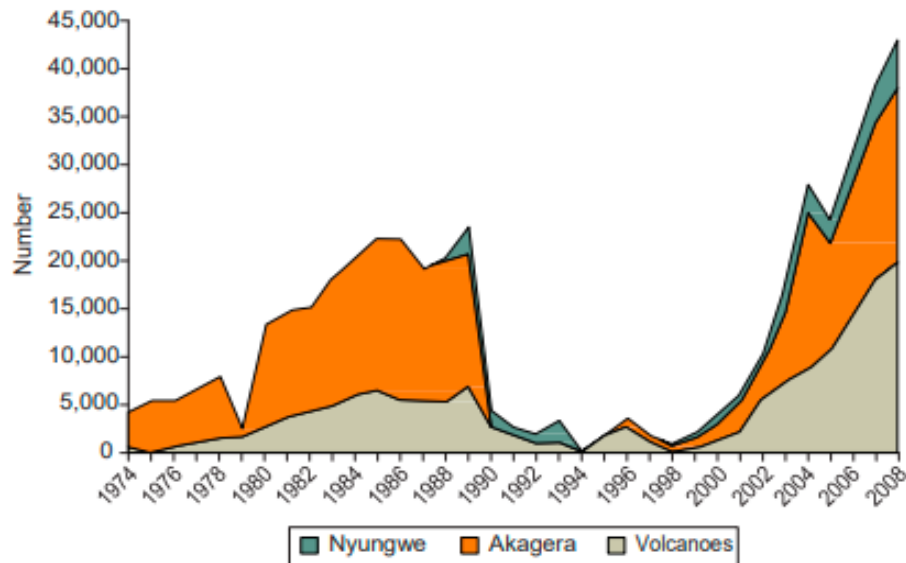


Figure 2:Visitors to national's Volcano Parks, 1994-2008 [1]

Many tourists come to visit the gorillas in the Volcanoes National Park, they spend a lot of time waiting to find out where the gorillas are located. IoT-Based Gorilla Monitoring System (IoTGMS) proposed in this research project to provide an easy way for detecting the gorilla's location and its motion to inform the Rwanda Development Board (RDB) and its beneficiaries to know the location of gorillas in real-Time and their management. Many tourists come to visit the gorillas in the Volcanoes National Park, they spend a lot of time waiting to find out where the gorillas are located. IoT-Based Gorilla Monitoring System (IoTGMS) proposed in this research project shall provide an easy way for monitoring the gorilla's location to allow RDB and its beneficiaries easily remotely accessing gorillas' location via dashboard in real-time.

1.2 Background

Rwanda Volcanoes National Park (VNP) is one of the most visited parks by tourists in Rwanda. This park is located in the northwestern of Rwanda at the Kinigi sector, covering an area of 160 km². The park including 5 volcanoes namely Karisimbi, Bushokoro, Muhabura, Sabyinyo and Gahinga.

In 1979, the Virunga region's first official mountain gorilla tourism program was launched by Bill Webber and Amy Vedder with funding from the African Wildlife Foundation, World Wide Fund for Nature, and Fauna and Flora International. It was one part of the three-part approach of the Mountain Gorilla Project, which also included antipoaching and education programs. The gorilla tourism program had a dual purpose: providing the Rwandan government and park authorities an incentive to conserve the VNP and the animals within it from the threat of proposed conversion of 5,000 hectares of the VNP for agricultural purposes; and generating local employment and tourism-related revenue. The program subsequently evolved into what is now the International Gorilla Conservation Program, still organized as a coalition of the three agencies. Two wild groups of gorillas were initially habituated for tourism visitation purposes, with strictly enforced limits on the number of visitors and length of visits. Below is the geographical map of area contained gorilla in Rwanda[2][3].

1.3 Motivation

Rwanda's image was damaged during the 1994 genocide to outside the country, and extreme poverty has taken its toll on Rwanda. Gorillas have become a good tool to showcase the new face of Rwanda to the world, where more tourists come from everywhere in the world to see gorillas, they do not see only gorillas but also the new image of Rwanda. Gorillas also play a key role in building the capacity of the poor in Rwanda and participate in capacity building of Rwanda citizen [2]. Another interesting part makes to focus on gorillas is because they are one of the most endangered animals in the world. We need to conserve them so that we protect their life by monitoring them so that their number increased and we need to provide good services to the tourists by detection zone covered by gorilla's status in real-time.

1.4 Gorilla Family structure

Gorilla's families are made up of 1 to 4 adult males frequently called silverbacks, some juvenile males, several adult females, and young. The oldest and strongest adult male silverback is usually dominant in the troop and has exclusive education rights to the females. Adolescent females transfer to another troop before reproducing at around 8 years of age. Generally, the first troop a female reproduces will become her permanent family.

The image below illustrates the female and male gorilla structure.



Figure 3:Mountain Gorilla Image [4]

Late arrivals do not receive the benefits of high ranking females such as having their offspring remain close to the dominant silverback for protection. It is for this reason that females most often join a lone silverback or a newly formed troop rather than a long-established one. Gorilla troops have a home range between 4-25 km² [7].

1.5 Problem statement

Rwanda has invested more effort in tourism mainly in gorillas as the rarest animals on earth. Tourists around the world are mostly attracted by Gorillas but by now there is no real-time system available for detecting and localization of Gorilla except circulating long distances in the forest without any information of Gorillas' location.

Before this research thesis, there was a wastage of time parks Guiders, where they didn't know exactly the location of Gorilla and results in the disturbance of Tourists by keeping waiting. Once gorillas have escaped the park it is very difficult to detect them, this could make disappearance from Rwanda Volcanoes National Park. The immediate notification is also very productive to

Parks' guiders for better management [9]. With these circumstances there is a need for a real-time system for detecting gorilla's location in real-time.

1.6 Study Objectives

The existing system used in Rwanda to manage gorilla is based on traditional capabilities where the park keepers are always there to know where the gorilla are located, their lives to manage the gorillas into whole park is too difficult. The purpose of my study is related to detect the current zone occupied by gorillas into Volcanoes National Park to enhance services given to tourists using technology

1.6.1 General objective

The general object of this research is to design and implement IoT based Gorilla monitoring system

1.6.2 Specific objectives

- ❖ Build remote connection between the NVP, RDB and its beneficiary based on IoT devices, and Establish MQTT communication protocol;
- ❖ Installing local cloud and database for storage
- ❖ Establish MQTT communication protocol
- ❖ Designing web based interface

1.7 Study Scope

In this research project, I developed an IoT Based Gorilla Monitoring system used to localize the gorilla in specific into Volcanoes National Park is large. The sensed values will be sent to cloud through MQTT protocol and being accessed by users remotely using dashboard.

1.8 Organization study

In this paragraph we are going to look at a summary of the activities done in each chapter.

Chapter 1: In this chapter, we find a summary of the whole project and what it is about. we see how Rwandan gorillas was being visited by different people around the world and significant role they play in building a country.

Chapter 2: In this chapter, we focus on assertions made by other scientists who are trying to determine the location of animals using a variety of technologies. Like GSM, GPS and ultrasonic and so on.

Chapter 3: In this section, we are looking at the way this research project achieved, MQTT technology is described in this section, also used sensors was explained, and the feasibilities of this research project and mathematical model

Chapter 4: The fourth chapter focuses on system analysis and design where the chapter focuses on simulations models and dashboard display and then we have found out who will use the system and how it will be used and when.

Chapter 5: This chapter focuses on explaining the results from the National Volcanoes Park using a graph.

Chapter 6: Chapter six includes conclusion of the job and give recommendations according to the result.

1.9 Conclusion

In this chapter we focused on the background of the research project and the area habited by gorillas and also both problems statement and the specifics objectives

CHAPTER II: LITERATURE REVIEW

2.1 Introduction

In the section we are reviewing works done by various researchers on developing animal monitoring system using different technologies.

2.2 Related work on IoT Based Gorilla Monitoring system

Many researchers have worked on projects that help us in the management, tracking of wildlife animals. When we look at the published books, we find that most of them use RFID technology and GSM modules, others use GPS and Lora technology, we can mention Kshama who has developed an animal monitoring system using RFID and GSM module, where they identified the location of animals at the time the veterinarian need to treat them, the SMS consists of the area where the animal is located is sent to the veterinarian's mobile phone as notification of current status of animals [10], and Prof. Joshi V has developed a Wildlife Animal Location Detection and Health Monitoring System that help him to determine the exact location of animals. T. Antoine et al. have been designed Wireless Tracking and Sensor System. Using Long Range Communication to Monitor Animal Behavior using GPS tracker and LoRa, he created a tracking geographical location and health status of animals using, temperature sensor, GPS and GSM [11].

According to T. Damrla et al who responded to the detection of illegal borders crossing by humans or other animals to illegal areas or country, has been achieved using a variety of sensors such as ultrasonic, seismic, and acoustic sensors. Those sensors were deployed into defined zone to detect illegal passing borders. Here there was places where people like to walk, the path made by people walking through the bush and it has a big surface; a valley between two mountains known to cross illegal aliens. With a view to identifying cross-border crossings they made a significant contribution, but were unable to identify the species of animals crossing the border even though they were able to identify illegal movement.

IoT systems will help to identify areas where gorillas are located and whether there are any non-monkeys in the zones, to achieve we have set up GMS system used to identify in real time the location of gorillas into Volcanoes National Park[5].

The conference done at France, A. Bounceur et al., their study on LoRa LPWAN, they started describing Bluetooth, zig bee and Wi-Fi focusing on their different gap including limitation, short range and failed to resist to signal noise and energy consumption. Due to emergency of Internet of things, several smart applications we implemented and they found that the previous technology were not adequate to be used In IoT application so other technology were thought are Sigfox, LoRa etc. They focused on LoRa show how it fit into IoT application due to its characteristics like code rate, spreading factor and bandwidth that make it to resist out of noise, because LoRa use the entire bandwidth it resists to channel noise and also success to fight against loss path due to its long range coverage. This technology was used in our proved solution [6].

The work done by N.Hayati [7] was based on LoRa technology, they design system for monitoring patient with mental disorder, the LoRa client is attached to patient body and LoRa Gateway installed in hospital and publish location, They use LoRa client device that comprise the Dragino LoRa shield Wireless, and the board is Arduino Uno, GPS and Wi-Fi module are integrated into board for tracking mental patient, the power bank were used as electrical sources where was connected to microcontroller. LoRa shield use radio frequency on ISM frequency band at 433 MHz, 868 MHz or 915 MHz. Gateway are connected to local server or the cloud so that the doctors or caregiver monitor patient remotely through the smartphone application in real time.

Using peer to peer ad hoc network technology, Philo Juang et al., designed system named ZebraNet, the wireless sensor network will have embedded collars attached to animals they build system to help tracking animals in a large area, S custom tracking node carried by animals, will operate as peer to peer so that it will deliver data back to researcher. The used attached collars are included GPS, flash memory, wireless transceiver and small cpu [8].

According to Xiahan Liu et al., they use internet of things technology to monitor wild animals. Those guys from china focused on three parts which are location tracking, habitat environment observation, and behavior recognition. In their studies they analyzed IoT platform for monitoring animals using satellite position receivers and for animals behaviors management they used

acceleration and gyro sensor and finally they use DHT sensor height to understand the behavior environment[9] . The animals are play great role to human life, so it is necessary to take care of them. To ensure the good health of animals, we need system that will detect the current situation including their diet, live streaming of animals' movement and behavior. For caring and tracking animals, RFID technology was used to identify animals. Camera sensor used to monitor their behaviors and also GPS used to track animals in their cages was proposed by Dr. Kirti Wankhede and Sayili Pednekar with this system that design smart zoo where collected information were stored into database so that the end user and staff can easily access in real time by the application. The Zoo Visitors get information of specified animals from the RFID tag attached with it, Zoo Keeper will track the location of animals using GPS , and finally the veterinarians can examine animals health status and the required medication if necessary [10].

After detecting that most of existing monitoring system is not suitable for long distance and are power consumption. Shengwei Lin et al., design and implement monitoring system based LoRa. The LoRa devices will collect in real-time activities and location and then transit to the cloud through LoRa Gateway. Experimental done shown that their system collected information are accurate, and able to cover long distance with low power consumption. The major component they have used are LoRa Devices , LoRa Gateway , Cloud and Mobile phone for displaying information [10].

The work done by Eyuel D.Ayelle et all., illustrate a system that use a dual radio Iot network architecture which are BLE and LoRa used to monitor wild animals activities based on LPWAN and BLE as short range technology for switching the operating radio based on proximity measures to optimize the performance and link animal cluster .LoRa gateway act as relay node by relying data to the cloud or server [11].

2.3 The summary of identified Gap

From the work done into previous research and project, more technology was used to track animals. The technology used does not work properly in the forest due to more obstacles like trees into the large forest that disturb the radio signal. Secondly they consume high battery power due to the usage of the GSM module. In this research, we developed an IoT based gorilla monitoring system used to detect and monitor the gorilla inside the national volcanoes park. The system uses low power battery consumption .

2.4 Conclusion

In this section 4, the overview of the system background was covered, and related work was reviewed provided guidance to enroll this research. Various IoT technologies were initiated in this project.

CHAPTER III: RESEARCH METHODOLOGY

3.1 Introduction

This section introduces the methodology approach used by the researcher for carrying out this proposed research project for detecting and locating the gorilla animals in Rwanda national park specifically Volcanoes park. Through this methodology approach, we present the chronological procedures followed to control the presence of gorilla and then give notification on dashboard. Through this methodology approach, we have used three main methods that include hardware development, software development and system simulation and testing.

3.2 System approach framework

In this section we look the description of the techniques used to achieve the output of this research project, by specifying the steps inside the system development from the start point to the end point to ensure the cooperation of all part of the system for full functionalities.

The following figure summaries the all approach used in this research project.

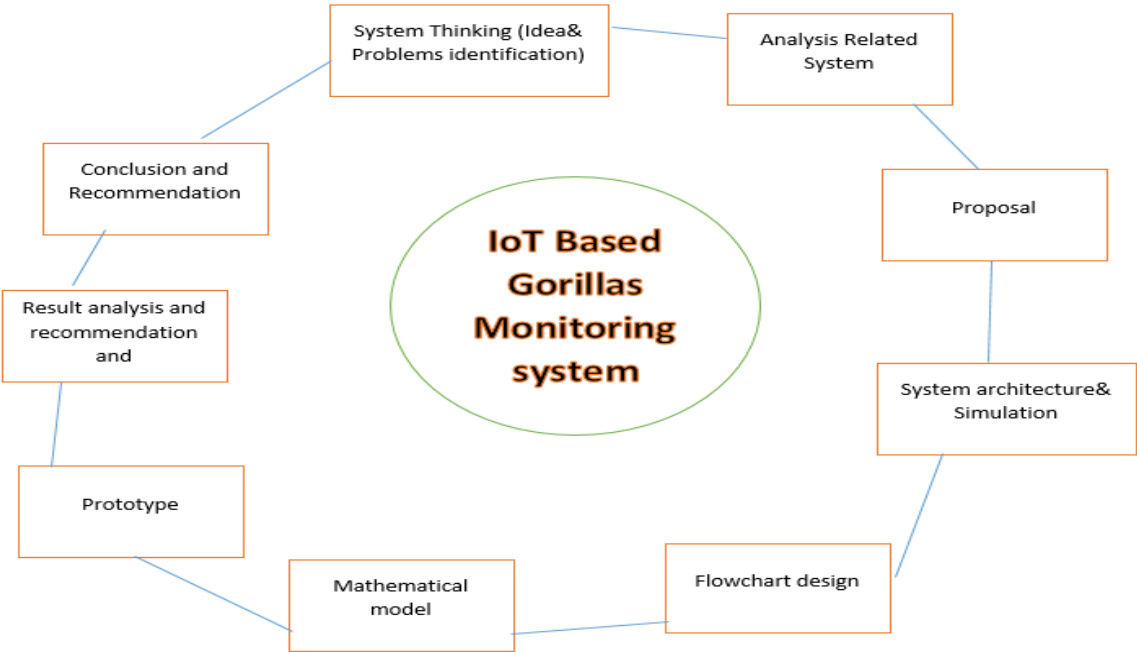


Figure 4: Research Project approach

From the above diagram, different component that made up an IoT Based Gorilla monitoring system was integrated to build the system. Each component will be explained in this chapter [12].

3.3 Scientific research methods

In this research project we have used qualitative, observation, and interviews methodology. The main purpose of this research is to elaborate the existing system, deed learning of my research so that I will come up with the good result.

3.3.1 Qualitative method

Qualitative methodology used for better understand the real problem and the needs of Rwanda Development Board (RDB) as it is the one in charge of the management of the national volcanoes park. This methodology carried out through surveys and interviews techniques with RDB staff and its beneficiaries, in order to identify common methods currently used by tourists to visit gorillas, and the problems they are facing with during gorillas visit and monitoring.

During of interview a sample of the RDB conservation department staff and Park visitors will be taken randomly and we hope that the collected information will be used to redesign the system for optimizing the gorillas monitoring and customer's services delivery[13].

3.3.2 Experimental methodology

With this technique we have to design a system with respect to the client needs. All collected information are used to develop a prototype for detecting the gorilla and monitor the motion inside the defined zone. Into this phase the simulation and the prototype was designed with the help of the ultrasonic sensor which collect different height of animals passing around, PIR sensor keep detecting the motion and the color sensor capture the color of gorilla and the various collected from those sensors are combined together to ensure the gorilla's presence.

3.4 Research project Simulation

The simulation is important tools for project selection, it helps us to make deep analysis and search different alternative based on influences of the selected project and their output. The below is figure that show simulated IoTGSM project. The below Figure 5 shows the system circuit structure of IoTGSM designed from proteus simulation software.

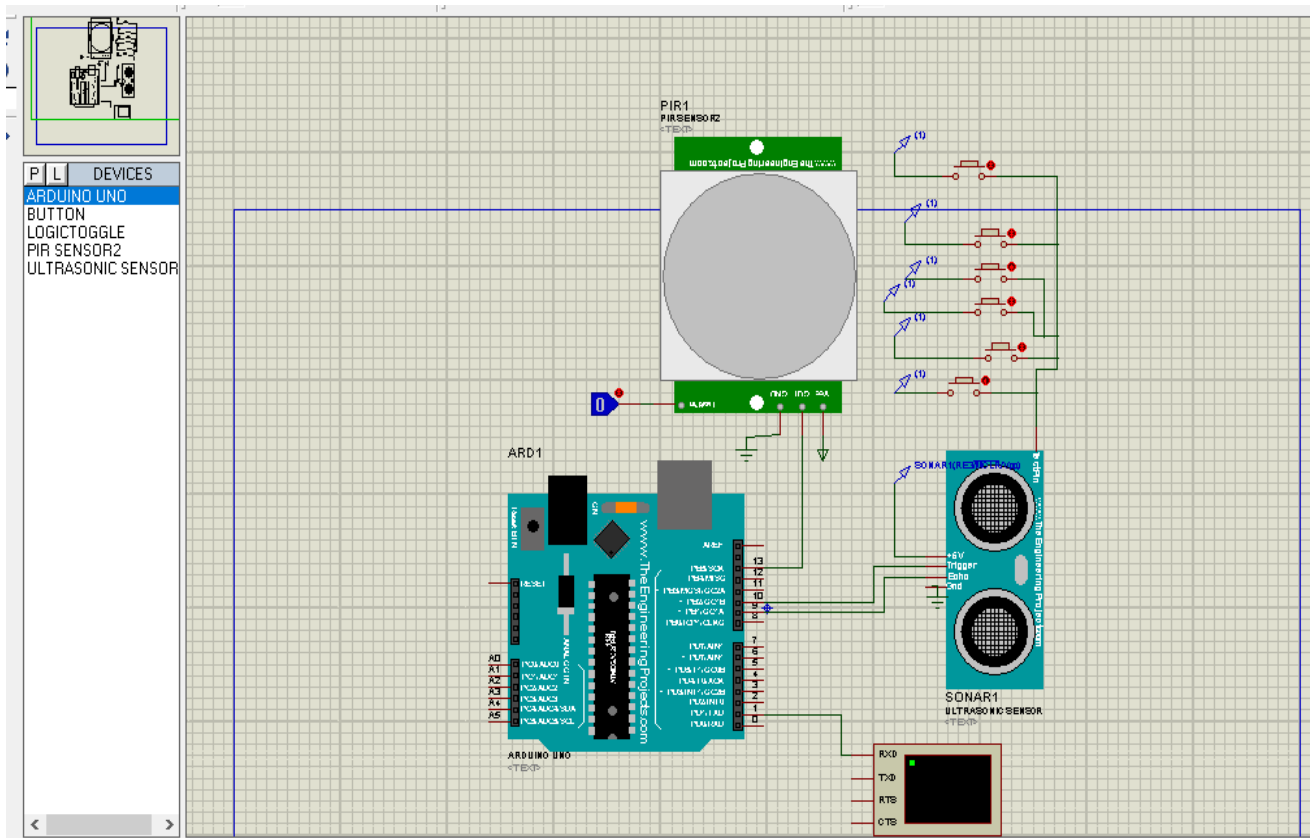


Figure 5:Simulation virtual hardware circuit

Project simulations can be also used to define the common field with high potential risk and include appropriate checks and balances into the project management plan to reduce those risks [14].

3.5 Prototype Modeling

The prototyping it is blueprint of the final system. It shows how the functionalities of system is inefficient performance compared to the actual software. The below figure shows all process step by step we used to build useful prototype and actual system.

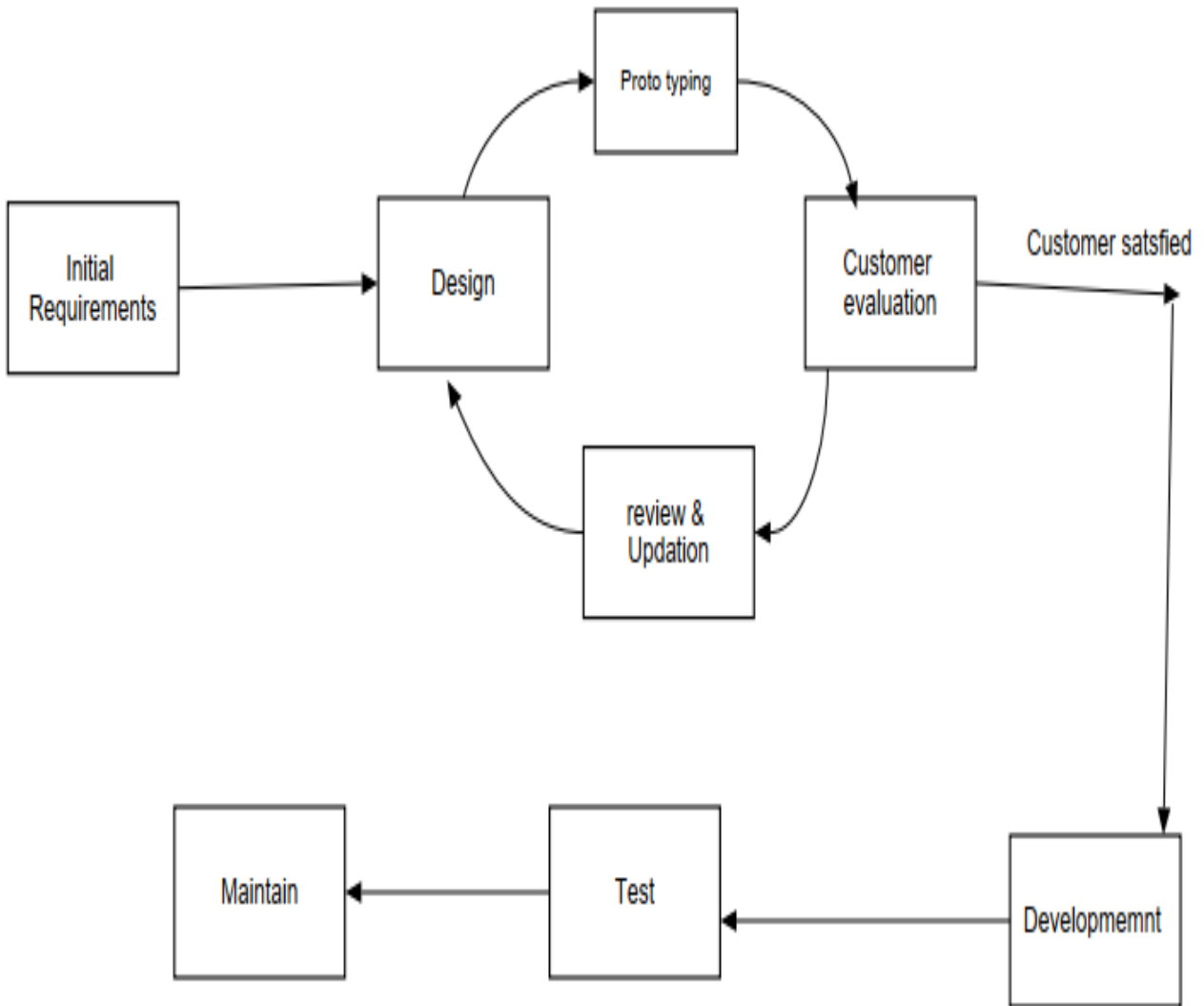


Figure 6:Prototype modeling structure [15]

During prototyping we used the device with low accuracy, low cost compares the actual project for improving customer satisfaction.

1. **Initial Requirements:** During this phase we to hear what the users or our client need from the system. We collected all the requirements gathering and analysis of the IoT based Gorilla Monitoring System. Different tourist was interviewed to know the requirements of the system and RDB staff.
2. **Design:** After Collect and analyzing the requirement we started designing for the IoTGMS. Only we included the important aspects of the system, which gives an idea of the system to the user of the system.
3. **Prototyping:** This is the repeatable phase. From the previous design we have to modified form the first prototype of our IoTGMS system which represented the working model of the required system.
4. **Customer evaluation:** In this phase, we present the prototype to the end user for evaluation and criticize the designed prototype. The comment and wishes from the customer must be recorded to be redesigning prototype according.
5. **Review and updating:** The Next step is to review the predefined prototype and redesign with respect to the claims from the system. The new prototype refined to fulfill user requirements specification. This phases continued until the customer user will be satisfied
6. **Development:** When the user of the system satisfied, the prototype we need end the this prototyping phase for the development
7. **Testing:** Once the system was developed and satisfy user's needs we need to test for ensuring availability of service and its performance
8. **Maintenance:** This the phase after developed and tested system to modify and update the product. This phase was not ye used in this research will be used once RDB accepted the implementation

3.6 Data Collection Methods

This is the part including the method used for data collection. In this paragraph we describe the methodology used for collecting data such are interview, observation and documentation in my research. For that I have used those techniques to come out with this system

3.6.1 Interview

The interview method was used to get more information related to IoTGSM, The RDB staff, and its beneficiaries by interviewing different information related to my own system

3.6.2 Documentation

With this technic, we used different resources such as the internet, website visiting, papers that are written by different researchers.

3.7 IoT Based Gorilla Monitoring requirements

The IoTGMS is system for monitoring the gorillas in the Volcanoes National Park aims to detect the presence of the gorilla inside the park. The system is made up by sensor node that used to detect the presence and the motion inside the park. This proposed system is made up two main part, which are hardware part and software part.

3.7.1 Hardware Part

We have different kinds of sensors used in this research project to use in this research project among them there are one for detecting movement, and identifying the colors, and measuring the height of animals each passing nearby.

The sensor is material that is very important in IoT project, are used to interact with physical to sensor its current status by sensing the physical phenomenon. The sensor is used also to simplify our lives condition for example by turning on the door once sense the vehicle presence and so on. In this research project to sense the presence and send notification [22].

The following are the type of sensor used in this proposed system

3.7.1.1 Ultrasonic sensors

Ultrasonic sensor was used in this research project for measuring the height of the gorilla and others animals into a defined zone at VNP, the highest height considered in this research is 200 cm. As it shown in following figure 7, the ultrasonic sensor emits a frequency sound wave, which move straight forward until reaching the animal side or any other obstacle it encounters. Then after hitting an obstacle, an ultrasonic echo sound waves reflected back to receiver. In line with that mechanism we are able to calculate or determine gorilla's height by using the speed of electromagnetic radiation in free space and the time the signal takes for both forward and backward travels [18].

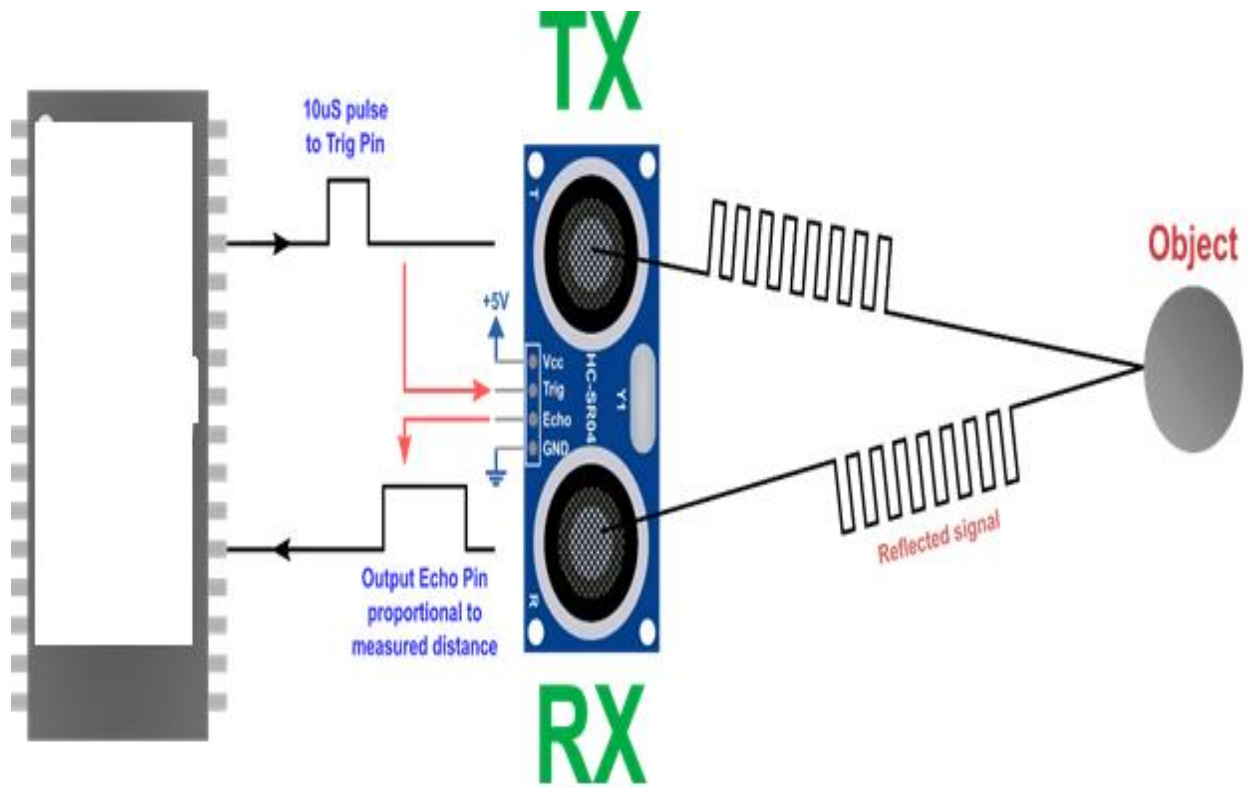


Figure 7: Ultrasonic Sensor Image [16][17]

3.7.1.2 PIR motion sensor

PIR sensor standard by Passive InfraRed is sensor which are made of a pyroelectric sensor , can detect levels of infrared radiation. Everything emits some low level radiation, and the more heater something is, the more radiation is emitted. The below **Figure 7** the PIR sensor was used to sense the motion of animals that are passing nearby the sensor nodes in the park



Figure 8:PIR sensor Image [19]

This type of sensor can be used to handle different of tasks that include even the security issues, but now it is used to ensure the presence of animals especially gorilla when it is combined with ultrasonic and color sensor [19] .

3.7.1.3 Color sensor

Color sensor is a type of "photoelectric sensor" that emits light from electricity, and then recognizes the light reflected in the back by receptive objects. This kind of sensor can determine the light received by red, blue and green and making possible to recognize the color of an object. we used this type of color sensor to make sure that the color of the animal detected is that of the gorilla [20].the next Figure 9 is color sensor image used in this research project



Figure 9:Color sensor Image [20]

3.7.1.4 ESP 8266 Wi-Fi MCU (NodeMCU board)

The ESP8266 Wi-Fi microchip with TCP/IP stack which has microcontroller capabilities shown at figure, is its self-system on chip (SOC) that contain TCP/IP protocols that can allow microcontroller to have access to the Wi-Fi network. ESP 82 66 module play a big role in IoT project due to its build-in Wi-Fi and it can work as an access point by service Wi-Fi to another device. This model was used in this research project to enable wireless communication where the sensors such ultrasonic sensor, PIR sensor and color sensor were able to publish the collected data from the environment to the remote server (MQTT broker) and then at the other side the broker provide the access to the subscribers such as RDB staff and its beneficiaries to view the information from server.

The following Figure 10 is ESP8266 module that was used for providing Wi-Fi connectivity



Figure 10:ESP 8266 Image [37]

3.7.1.5 Arduino Uno Board

The Arduino Uno is board developed by Atmel, it used for processing the data. This board have set of digital and analog input/output (I/O) pins acting as interface that allow various expansion board and others circuits to interact with it.

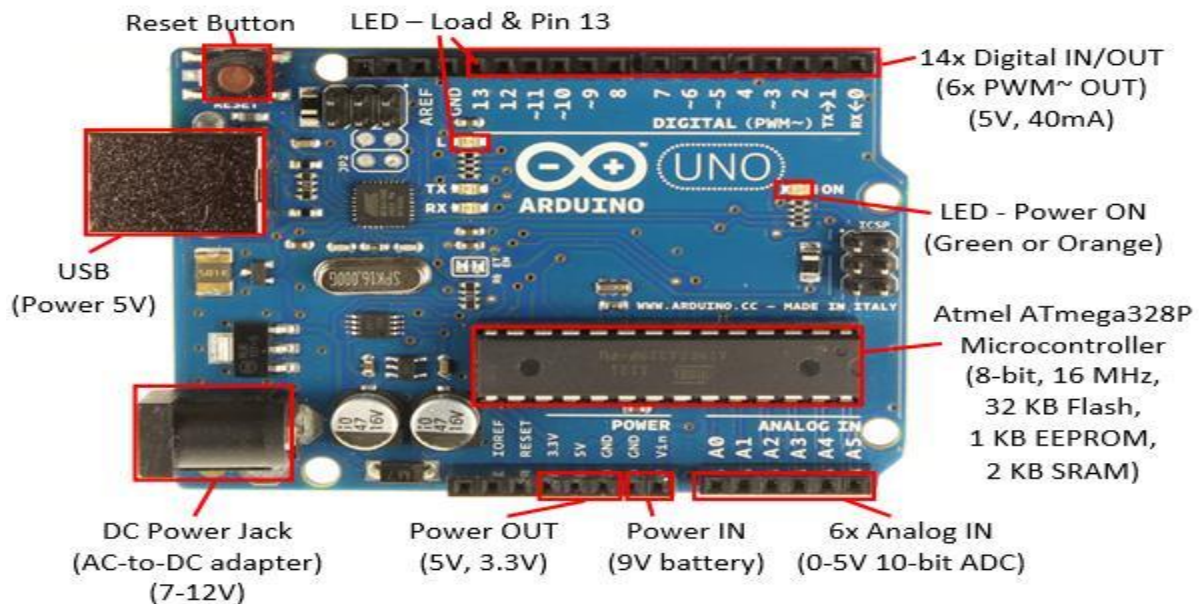


Figure 11:Arduino Uno:[21]

3.7.2 System Software Part

3.7.2.1 Arduino Software (IDE)

The Integrated Development Environment (IDE) is software platform that has built-in c, c++. We can write code and debug for compiling the code, including complete error messages and other information. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

3.7.2.2 Node-Red application

Node red defined as software tools that frequently used to build the IoT project, the node red running over node JS technology. Into this research project Node Platte was used with different sensor such as ultrasonic, PIR sensor and color detection sensor for detecting the presence of gorilla selected zone in NVP.

3.7.2.3 MQTT communication Protocol

In this paragraph we refer to the client, server/ broker and connection establishment. MQTT (Message Queuing Telemetry Transport) is one of the IoT protocol commonly used to transmit messages between devices buy subscribing on defined topic and publish the content for IoT based gorilla monitoring system use different sensor. The sensor node will publish data on subscribed topic so that we now the viewed those on dashboard. MQTT is divided into two part which are client MQTT and broker MQTT.

3.7.2.4 MQTT Client

This is the part that initializes the communication, both publisher and subscriber are the MQTT client, the publisher, and subscriber working concurrently for publishing the messages on the broker, the other side the MQTT subscriber is receiving the published messages from the MQTT broker. Here the sensors are connected to Arduino Uno with the ESP8266 module are running the

MQTT library that allows them to publish the message to a MQTT broker server over the internet so that the published information will be accessed anywhere [33].

3.7.2.5 MQTT broker

The broker is like server it handles multiple both publish/subscribe the MQTT client work closely with the MQTT broker. The broker is considering as the central or the heart of any publish/subscribe client. Refers on the deployment, a broker used to handle up to several simultaneous connected MQTT client that are used to publish information from physical environment. The broker's duties include filtering the received message and ensuring the specific subscribed message and the message will be sent to the subscribed topic and the broker also holds the session data of all clients that have persistent sessions, including subscriptions and missed messages (more details). Another responsibility of the broker is the authentication and authorization of clients. Usually, the broker is extensible, which facilitates custom authentication, authorization, and integration into backend systems. Integration is particularly important because the broker is frequently the component that is directly exposed on the internet, handles a lot of clients, and needs to pass messages to downstream analyzing and processing systems. In brief the broker acting as central where every message pass-through [22].

3.7.2.6 MQTT Box

The QTTBox allows us you to create MQTT clients that able to publish or subscrip to certain topic. Both publish and subscriber connected to brokers. The following is image after publish topic through QTTBox

3.8 WIFI

The Wi-Fi technology is wireless network technology used to transfer information, file using radio frequencies. It allows us to connect to the internet so that we access the system anywhere.

802.11 Wireless Specification and Standard

802.11a – This have characterized by 54 Mbps and it has frequency of 5-GHz band

802.11b – This standard has the speed 11 Mbps and the 2.4-GHz.

802.11g – This standard has speed 20+ Mbps and 2.4-GHz band.

Here is the technical comparison between the three major Wi-Fi standards.

3.9 Database storage

Influx database is database engine that will store the published into relational database, the database data are store into measurements tables. The dataset for storing IoT based gorilla system was name Gorilla_db. The following is screenshot that illustrate the structure of Gorilla_db using different SQL commands.

3.10 Detection methodology

The Gorilla play big role to Rwandan economic growth during visitation of park, for that reason we need to have an IoT system for monitoring them in the park in real-time. The system is made up sensor node and MQTT as communication technology. For Detecting gorilla require both height range measurement by ultrasonic and color sensor range must be working together.

CHAPTER IV: SYSTEM DESIGN AND ANALYSIS

4.1 Introduction

Nowadays several sectors are digitalized, therefore multiple systems were designed to solve the complex problems. Building a system is no different from building a house where a developer follows the step by step to build a better system. The first step is ideas, the second is to draw how the system will work and show it to the beneficiaries for input and the third step is to install blueprints or prototypes final step is implementation. in this article we will see who uses the system and what the system will be used for and the operational system, the IoT based Gorilla monitoring system model will be proposed, simulation parameter, and prototype of the project. This article is divided into two main part which are system analysis and system design[23].

4.2 System analysis

This is the tricky part when it comes to developing a new system specially IoT system , because it helps us understand how the system will be used , who will used it and how the new system will change the productivities and simplifies the work by minimizing human intervention , through the system analysis phases we are able to identifies improving [23].

4.3 System design

Today many researchers are working on very complex systems to solve serious problems. To achieve this in the best possible way they use simulation, prototyping so that they can provide a reliable solution to the problems that have arisen.

Projects that involve complex situations can be described as adaptive complex systems, consistent in multiple interdependent dynamic components, multiple feedback processes, nonlinear relations, and management of hard data (process dynamics) and soft data (executive team dynamics). In this study, through a complex network, the dynamic structure of a project and its trajectories are simulated using inference processes. Finally, some numerical simulations are described, leading

to a decision making tool that identifies critical processes, thereby obtaining better performance outcomes of projects.

In this paragraph we describe how the project is simulated. To simulate it we use proteus professional 7 and related library to my sensors and Arduino.

4.4 Gorilla Detection Modelling

For confirming that the gorilla has been detected, we have to evaluate the measurement got from separate three sensors. The first step was to detect any pass by animal through PIR sensor and then after taking animal height measurement by using ultrasonic sensor. Moreover, after detecting and taking the measurement of any animal that pass through under the sensor node mounted on the top of 200 cm from the ground, we have employed a color sensor for identifying the color components of the detected animal. These color components include Green(G), Red (R) and Blue(B).

The following formula gives the mathematical modelling of Relative Luminance of anything based on its color components (red, green and blue) [24]. Relative luminance is the relative brightness of any point in a color space, normalized to 0 for darkest black and 1 for lightest white[25].

$$L = 0.2126 * R + 0.7152 * G + 0.0722 * B$$

Where R, G and B are representing Red, Green and Blue color components respectively. The coefficients in the formula above reflect human eye sensitivity to the particular color component: human eye senses green component most luminous, red one - a bit less and blue component is the least one of three.

Therefore, the gorilla detection is confirmed when the height of the animal detected ranges between 140 and 165 cm [26], and simultaneously the color components values (Red, Green and Blue) of the animal detected are all the same and equal to 192 (R=G=B=192)[27].

Detection algorithm: $140 \leq \text{animal height in cm} \leq 165$ and color components (R=G=B=192)

By combining the all the above value, we are able to detect the presence of gorilla into the park [28],

4.5 System model Design

With the system architecture we define the model that define the structure, behavior and more attribute related to this system. The structure contain all the components and subsystem developed , to optimize the result out of the system .This architecture we have used it show us how sensor node are connected each other .the structure contain three important part which are sensing part, processing part and storage[29].Figure 12 is system structure model include sensors mounted into the park for collecting information to be preprocessed by middleware component (microcontroller) , and forwarded to cloud storage via MQTT communication protocol for processing . After being processed the RDB beneficiaries will access them using HTTP/web graphical user interface.

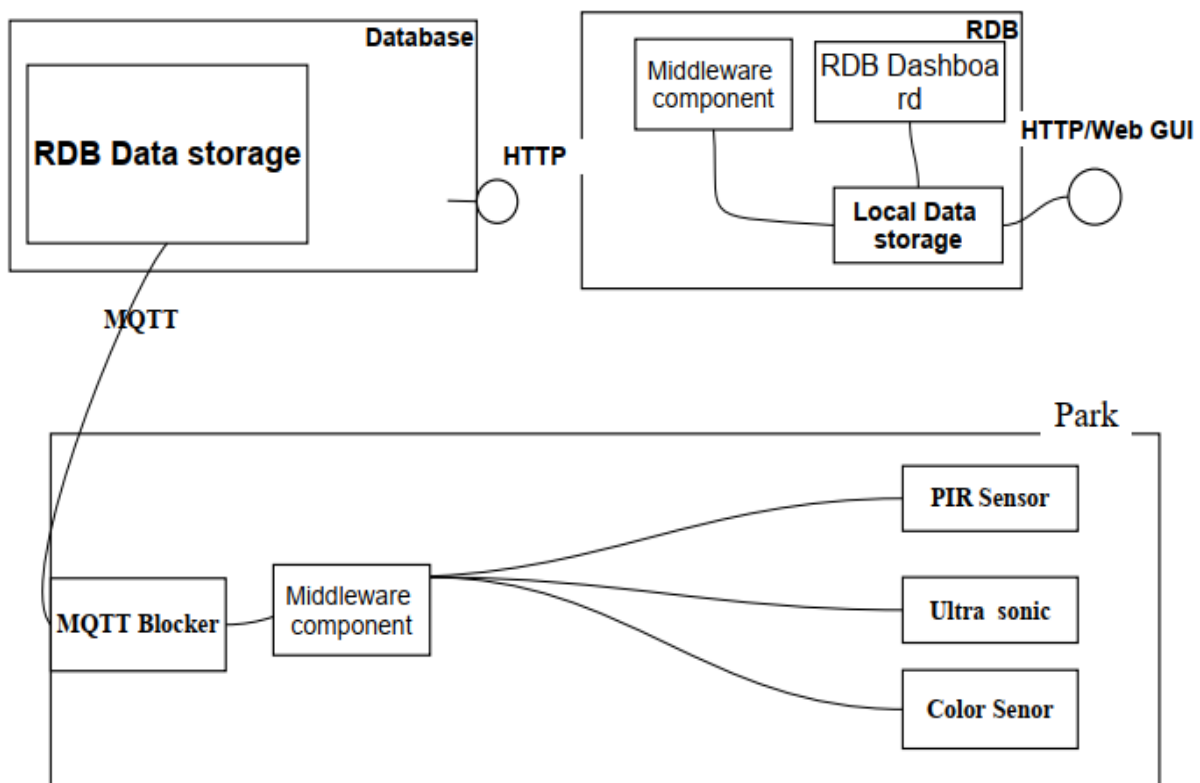


Figure 12: System architecture

With the use of MQTT and Wi-Fi technology the sensor node transmits the collected data to the server, where the RDB and its beneficiaries can access the processed data and store it into the database.

4.6 System design process

A flowchart is a kind of diagram that describe the workflow of system. With the flowchart you understand, a step-by-step approach to solving the identified problems.

In this paragraph we explain how each sensor works to give us information about the current location of gorillas.

1. Ultrasonic will help us determine the height of the gorilla, when it senses the height between 140 cm and 165 cm, gorilla's height will be notified
2. PIR sensors are used to detect an animal's motion. while the motion is no longer detected and the ultrasonic keeping detecting the height, in that case physical checking is needed to identify whether animals is not sick or other cause.
3. Color sensor were used to detect gorilla's color whose range is RGB (192,192,192).

RGB standard Red Green Blue respectively

By using the below diagram we illustrate a solution model to a given problem by analyzing, designing, documenting or managing a process or program [30]. The ultrasonic, color and PIR sensors are cooperated together to detect the presence of gorillas in the predefined zone inside the park. Every sensor sense information and send to microcontroller for preprocessing.

As seen on the following Figure 14, the start point is where our sensor nodes are mounted for reading data from the park. The reading value are stored into database for processing. The height of gorilla varies between 140-165 cm with black gray color in which values is RGB =192. In case both parameter from ultrasonic and color sensor matches, show that the gorilla is detected, otherwise others animals are detected. With the help of PIR sensor it is possible to detect the detected animals motion in the zone.

Flowchart diagram

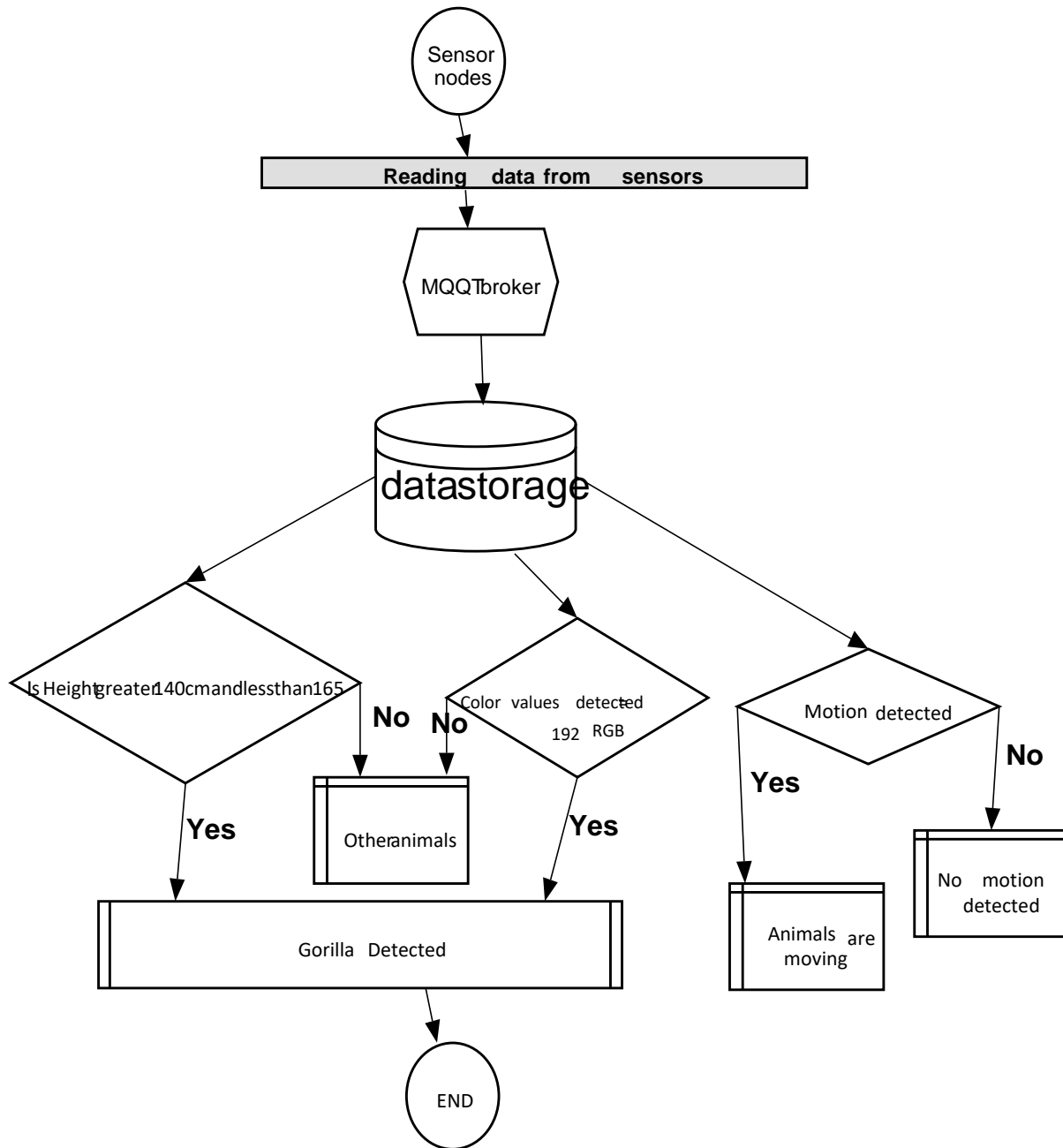


Figure 13:Software development process

4.7 Hardware design process

In the project we used hardware component 4 including this Arduino, ESP 8266, and sensors those sensors are connected to Arduino Uno through jumper cables. *Figure 14* shows the physical circuit connection of IoT GMS prototype

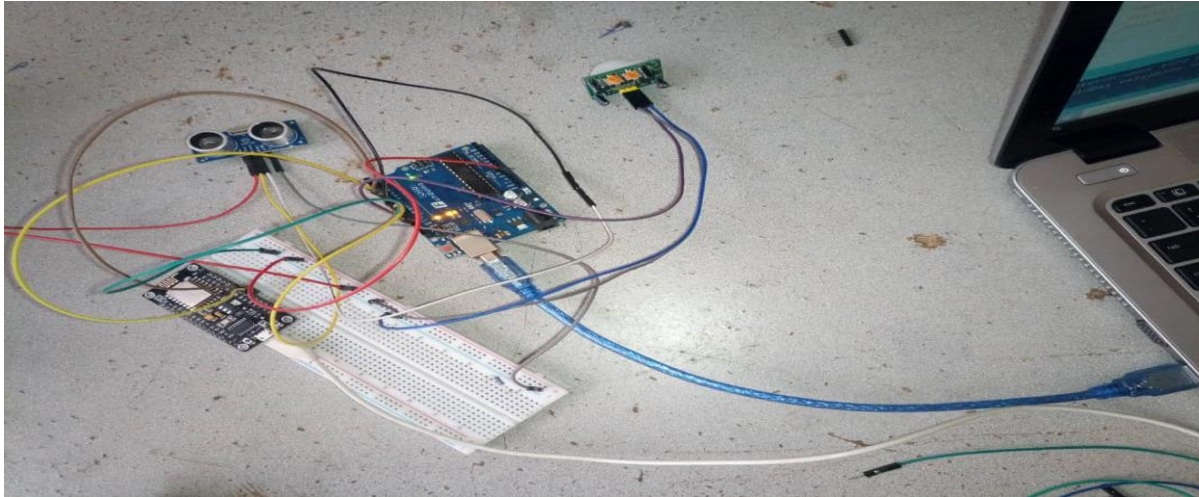


Figure 14: prototype connection model

4.8 IoT technologies

Internet of thing technology has smart network that enabled to allow different network protocols to communicate over the network. For the sensor node collect the data from the physical environment they may be sent to the gateway so that to communicate to the gateway.

4.8.1 Node –red palette structure

Today technology is advanced in internet of thing, the node-red platform is commonly used in different IoT project, it allows us to install and manage the local database. The succession node or palette are designed and presented into workspace where the nodes are organized. Through the Figure 15, IoTGSM structure components to be shown on dashboard.

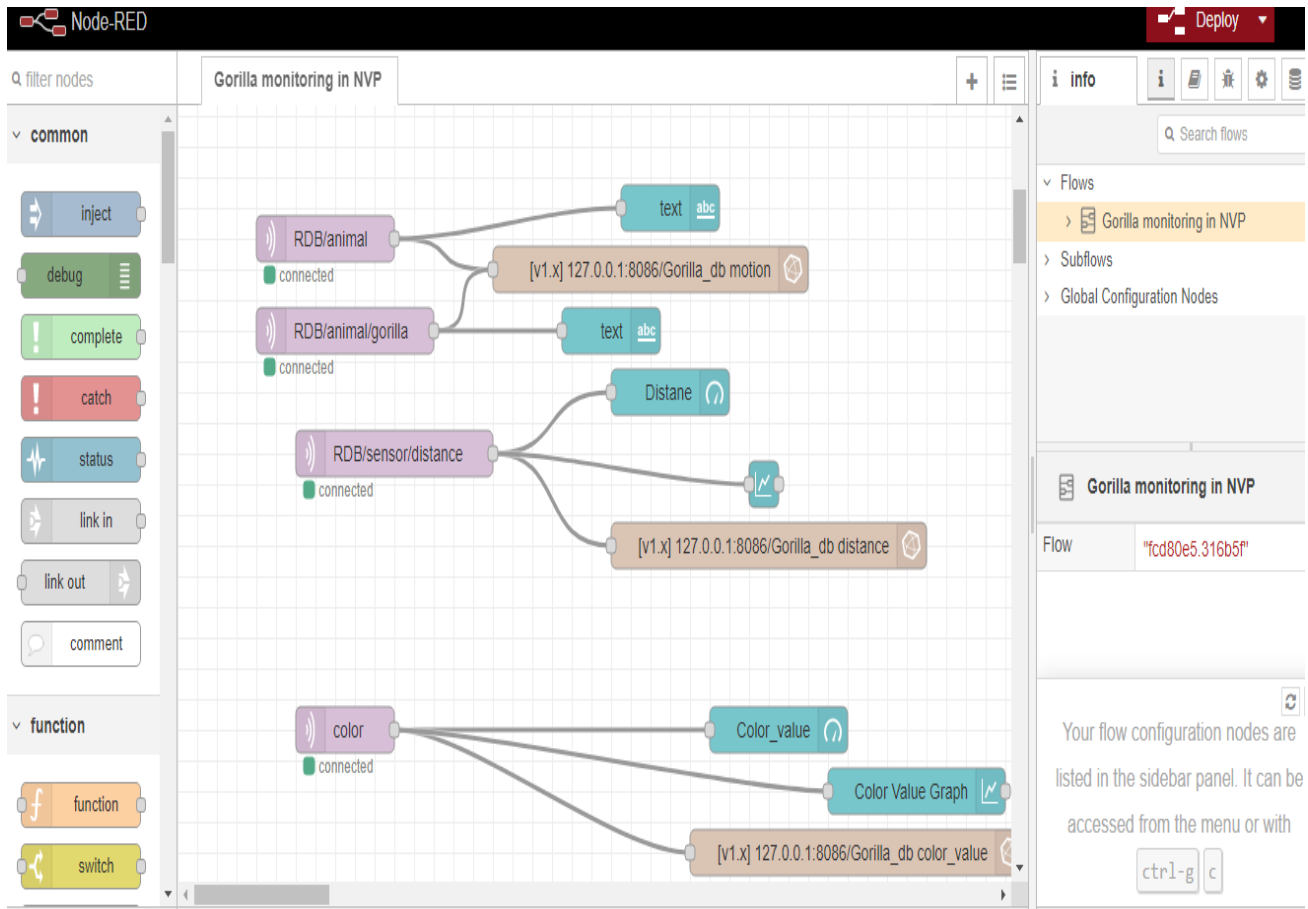


Figure 15:node -red palette Image

4.8.2 MQTT structure

MQTT is designed protocol to help implementation of IoT project by enabling the lightweight publish/subscribe messaging protocol used for M2M (machine to machine) telemetry with low throughput. It was designed by Andy Stanford-Clark and Arlen Nipper during 1999 for establishing the Oil Pipeline telemetry systems over satellite. The below is the structure of MQTT[31].

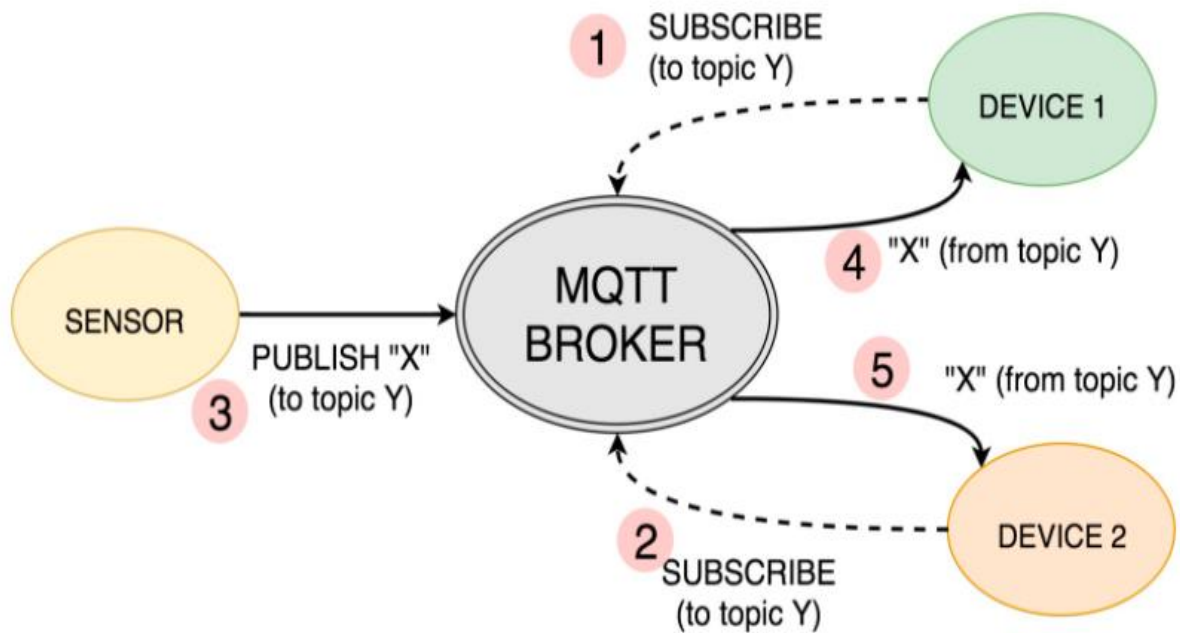


Figure 16:MQTT Structure image[32]

The above picture is MQTT with published data different sensor including ultrasonic sensor and PIR sensor. Ultrasonic sensor use topic named RDB/sensor/distance where a computer device owned by RDB and its beneficiary will subscribe on that topic to be aware the current zone occupied by gorilla in Real-time

The mqtt client Create multiple simultaneous MQTT clients connected to same or different MQTT brokers with secure communication that use TCP/SSL secure protocol [33].

CHAPTER V: RESULTS AND DISCUSSION

In this chapter, we analysis the performance of IoT Based Gorilla monitoring system. As sensor node via MQTT communication protocol send the sensed data to the cloud where the end users are able to easily access them by subscribing to the published topic. Distance, Motion and color values are observed graphically on dashboard based on date and time. The displayed sensed data are in form of graph, Gauge. We analyze those values from sensor node in the park so that help us understanding how our research resolved the problem and the data found that make clear the outcome pursuant the published information on RDB dashboard.

5.1 Graphic result explanation for simulation

With the help of Simulation software such as proteus and other we get virtual result from research project but data are not real, as seen on the virtual serial monitor once you push blue Logic toggle button the into the simulated, it seems that the gorilla was detected in zone A. the Figure 17 as seen below , using blue toggle button in the simulated project show how the result will be displayed on the dashboard through virtual display .

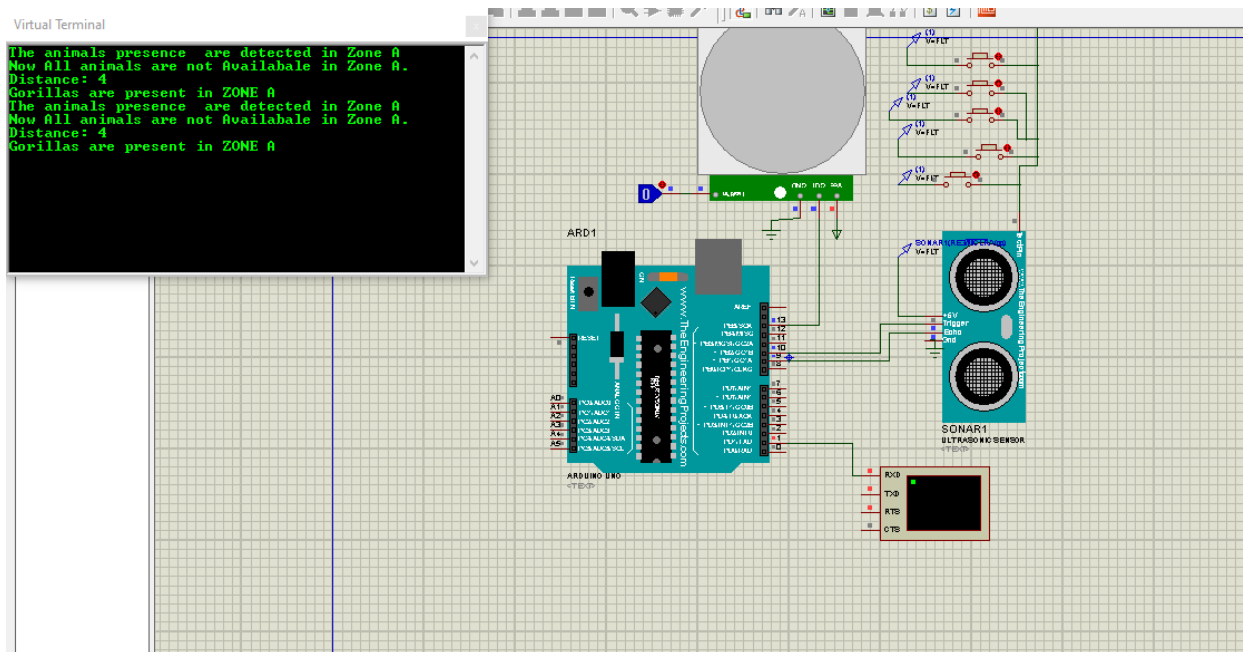


Figure 17:Simulation output display on Virtual Monitor

5.2 System dashboard analysis

The sensor were installed at 200 cm from the ground or 0 cm . this happen once sound wave sent by the ultrasonic sensor does not hit any obstacle. The height of object displayed on the dashboard are equal to the maximum values which are 200cm minus the height of that animal.

5.2.1 Dashboard analysis one

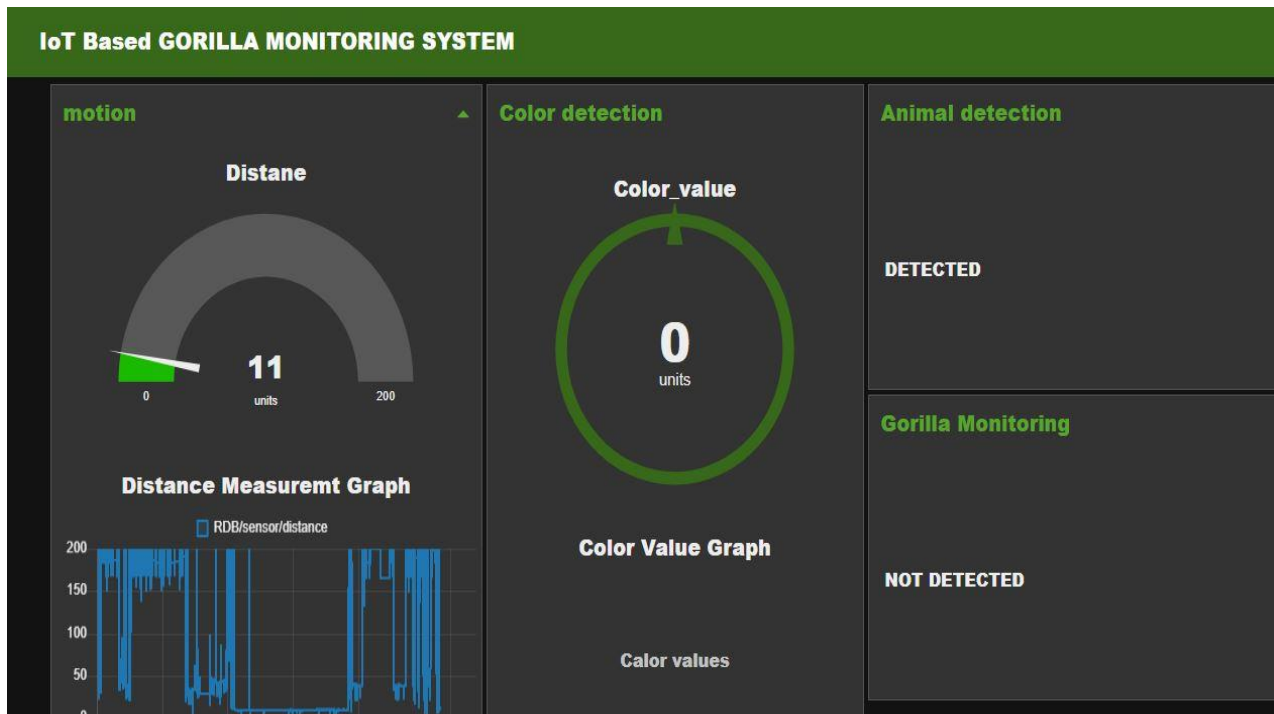


Figure 18:animals detected

As seen on the above dashboard, the distance measurement graph we have 11 cm that illustrate the presence of other animals inside that zone. that is way the message “animal detection =” DETECTED” but Gorilla Monitoring =” NOT DETECTED” As shown above on this dashboard there is motion detection which means there are animals but not gorillas. This will help tourists not to be killed by dead animals when visiting the park.

5.2.2 Dashboard analysis two

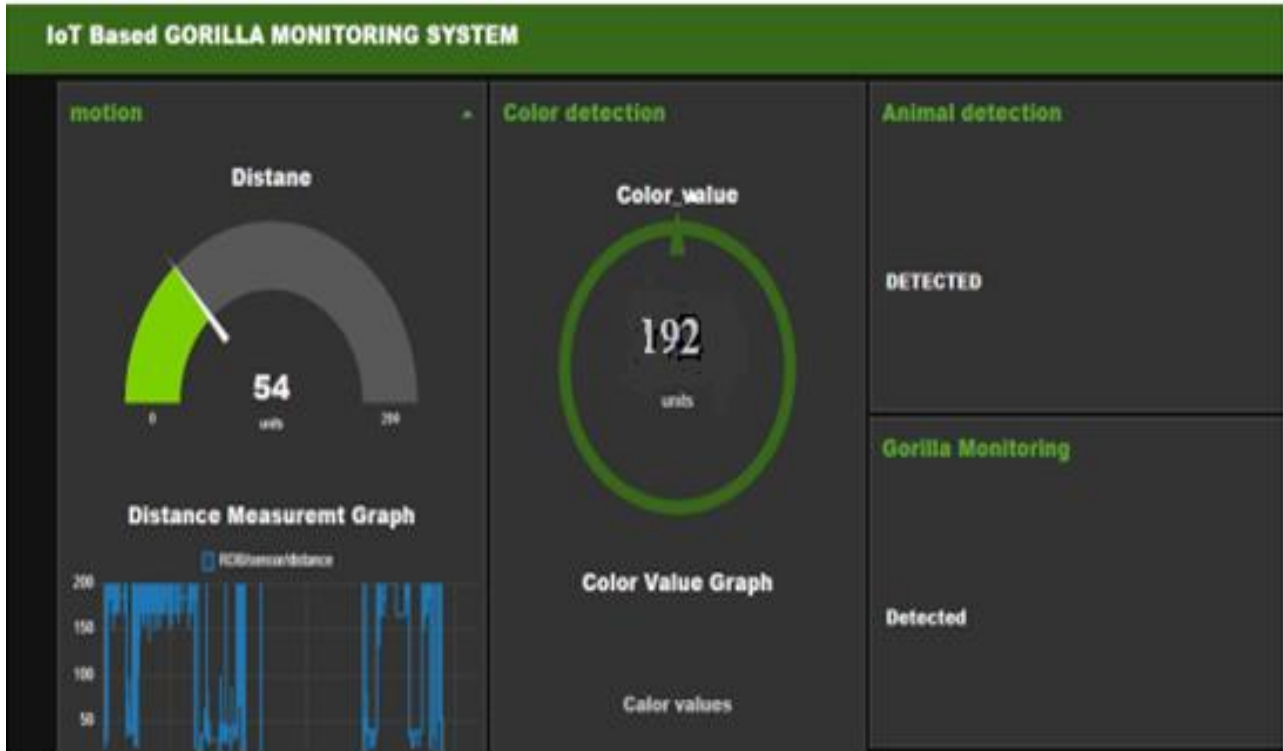


Figure 19:Gorilla detected

The above information show presence of gorilla into the park. This happen when distance is between 35 and 65 cm because gorilla height varies between 145 to 165 i.e. $200\text{cm} - 145 = 35\text{ cm}$ and $200\text{ cm} - 165\text{ cm} = 65\text{ cm}$. The gorilla height is combined with its color RGB values 192. Gorilla color black gray match with GRB (192,192,192). From the above various 54cm (distance), color value 192 once displayed, the ensure gorilla is detected.

5.3 MQTT interface

Once the sensor node publishes the data to the broker server, the different beneficiaries of the system will subscribe to that topic, and start receiving the information once there are connecting to the Wi-Fi.

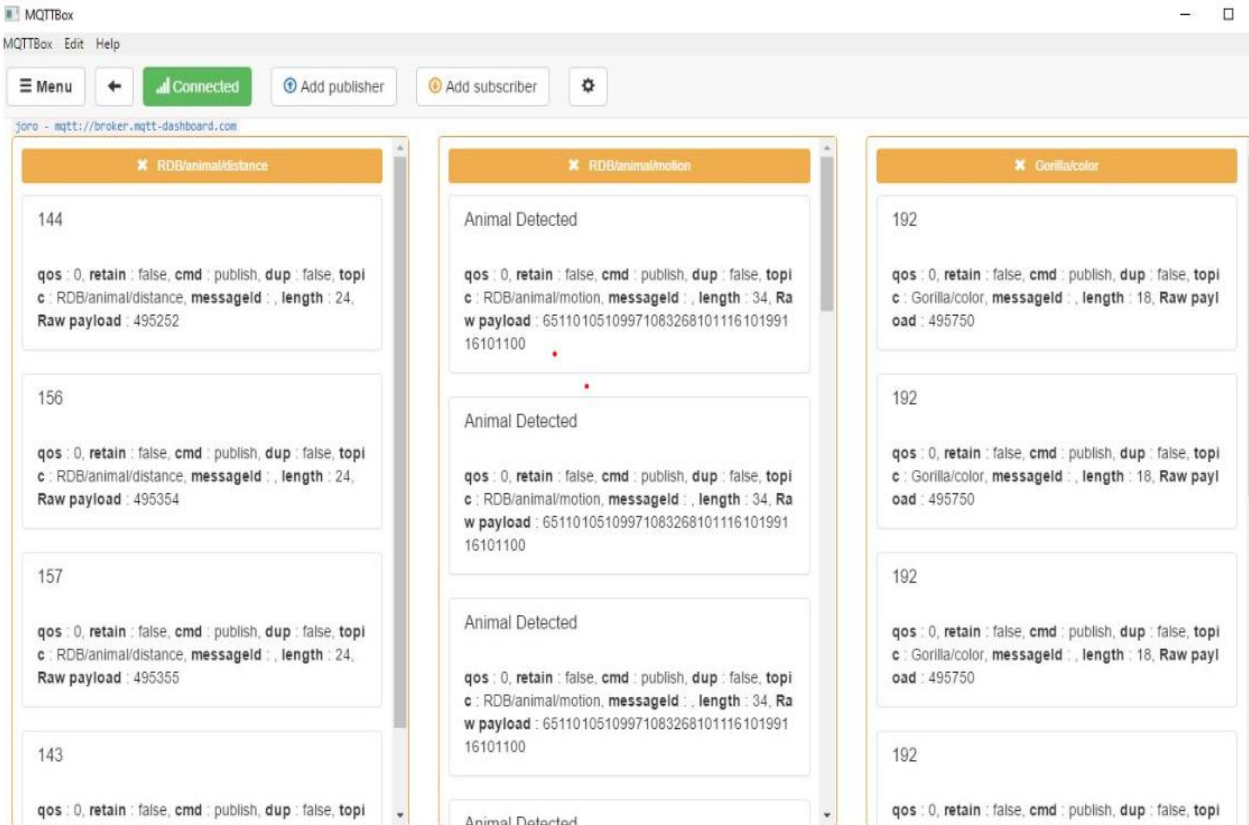


Figure 20:MQTTBox connection

As shown above Mqtt interface, the distance height is being displayed in the first column as published on the topic “RDB / animal / distance” when the height was varying between 140-165 cm on the dashboard it was found that the gorillas had been detected. And on the topic "RDB / anima / motion" is the one helped us to know if the animals are moving as shown the message displayed is motion detected, on the topic "Gorilla / color" he gave the original numbers mixed with red and blue colors.

CHAPTER VI: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The IoT based monitoring system were designed to facilitate the RDB management of gorillas in Volcanoes National Park. Most of the animals monitoring systems were established for specific purposes and generally have achieved their stated goals. However, the programs overlap significantly, and some problems underuse data and samples collected. For example, ZebraNet system was used in tracked animals in a large area at Impala Research Center in Kenya. This system was designed also to improve the management of Rwanda Volcanoes National Park currently supervised by RDB and used to identify the current location of gorillas at the predefined zones into Volcanoes National Park. The system is made up with ultrasonic, PIR, and color sensors connected to the Arduino and ESP 8266 that will publish the information of current status of defined to dashboard using MQTT communication protocol. With the corrected data, the system will help RDB conservation management staff to improvement the strategy of managing the national park and improving services delivery.

6.2 Recommendation

I recommend the Rwanda Development Board to use the IoT system like IoT Gorilla monitoring system to improve the management of NVP and service delivery. The use of this system will grow Rwanda economy and make Rwanda tourism more accessible and flexible.

I recommend future researchers to integrate Artificial Intelligent and Machine Learning for better and deeper analysis of Gorilla detection.

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