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College of Science and Technology

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

Research Thesis Title: Animal location Detection System Leveraging a Machine Learning Model and Raspberry Pi

Case study: Akagera National Park

A dissertation submitted in partial fulfilment of the requirements for the award of masters of science degree in internet of things: Embedded computing system

Submitted by:

Name: Fabrice MANZI (Ref. No: 221001953)

April, 2023

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Supervised by:

- Dr. Said NGOGA RUTABAYIRO
- Dr. Philibert NSENGIYUMVA

April, 2023

DECLARATION

I Fabrice MANZI, Master's student from the African Center of Excellence in Internet of Things, at the University of Rwanda, I declare that this research thesis is my original work and has never been presented anywhere in the world.

Fabrice MANZI

Ref: 221001953

Signed: …………………………

Date: 27/03/2023

BONAFIDE CERTIFICATE

This is to certify that this submitted Research Thesis work report is a record of the original work done by **Fabrice MANZI (Ref. No: 221001953**, MSc. IoT-ECS Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in the Internet of Things, the Academic year 2020/2022.

This work has been submitted under the supervision of Dr. Said NGOGA RUTABAYIRO and Dr. Philibert NSENGIYUMVA

Main Supervisor: Dr. Said NGOGA RUTABAYIRO

Date: ……

27/03/2023

Signature:

Co-Supervisor: Dr.Philibert NSENGIYUMVA

Date: ..27/03/2023

Signature:

The Head of Masters and Training: Dr. James Rwigema

Date: ……….

Signature:

DEDICATION

"To my family, who have always believed in me and supported me through all of my endeavors.

To my supervisors, **Dr. Said NGOGA RUTABAYIRO** and **Dr. Philibert NSENGIYUMVA**, who have provided invaluable guidance and support throughout my research process

And to the African Center of Excellence in Internet of Things (ACEIoT), whose financial support made it possible for me to complete my studies after not getting any scholarship in the beginning of the program.

Thank you all for your unwavering support and belief in me. This thesis is dedicated to you."

ACKNOWLEDGEMENTS

This work was supported by the African Center of Excellence in Internet of Things (ACEIoT), College of Science and Technology, University of Rwanda.

I am grateful to the African Center of Excellence in Internet of Things (ACEIoT) and the College of Science and Technology at the University of Rwanda for their support during my studies. I would also like to express my appreciation to the staff at ACEIoT and the rest of the University for their Contributions and assistance throughout my time as a student. I am grateful for the support, generosity, and kindness shown to me by the institution, as well as for the invaluable assistance provided by my family and fellow colleague

Topic: Animal location Detection System Leveraging a Machine Learning Model and Raspberry Pi

ABSTRACT

One of the biggest challenges facing tourists visiting Rwanda's national parks is the frustration of not being able to see their preferred animals. This can lead to disappointment and a negative overall experience for tourists, as well as challenges for park management. In this study, we aim to explore the potential of using machine learning, embedded computing system, and a client application to improve the animal-viewing experience for tourists at Rwanda's national parks.

To address this problem, we developed a system that combines a machine learning model (You Only Look Once, or YoloV5) with a Raspberry Pi and a client application (developed in React JS) to classify images and show the location of animals. This system utilizes cameras that are already deployed across the park, specifically in key areas where they are used to monitor the safety of the animals and ensure that tourists and guides are following the rules. The cameras capture videos in the form of frames, and the resulting images are processed by the machine-learning model on the Raspberry Pi to identify and classify the animals present in each image. The client application, developed in React JS, allows tourists to view the location of the animals on a map of the park.

In this research, we present the results of a one-component system and demonstrate its potential to improve the animal-viewing experience for tourists. It is important to note that to address this issue, the system needs to be deployed to multiple locations in the park, following the areas where the cameras are already installed. With the help of the guides and security personnel, we can identify additional locations to deploy the system to. With further resources and time, this approach could be scaled to cover the entire park, enabling tourists to plan their visits and easily locate their preferred animals

Overall, our research suggests that the use of machine learning and a client application has the potential to greatly enhance the animal-viewing experience for tourists at Rwanda's national parks, and could provide valuable insights for park management.

Keywords: Embedded Computing, Machine Learning, Object Detection

LIST OF ACRONYMS

YoloV5: You Only Look Once version5

ACEIoT: African Center of Excellence in Internet of Things

IoT: Internet of Things

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Introduction

Tourism is a vital contributor to Rwanda's economy, with foreign exchange earnings projected to grow at a rate of 25% per year between 2013 and 2018 [1]. However, one common frustration among tourists visiting the country's national parks is the inability to see their preferred animals. This can lead to disappointment and a negative overall experience for tourists, as well as challenges for park management. Currently the existing tool to know where animals are located is the guessing of the guides but they also get it wrong most of the time.

In this study, our aim is to investigate the potential of using machine learning, a Raspberry Pi, and a client application to enhance the animal-viewing experience for tourists at Rwanda's national parks. Our approach leverages the security cameras already installed in the parks, as well as the capabilities of an existing object detection model (YoloV5), combined with an image dataset. After training the model, we integrated it onto a Raspberry Pi device to perform animal detection, record the location, date, and time, and send it to the cloud. This information is then displayed on a web application containing a map of the parks, allowing tourists to view the locations of animals and plan their visits accordingly. This system can help tourists have a better experience and can also enable the national parks and guides to provide greater customer satisfaction.

To our knowledge, this is the first study to investigate the use of machine learning, a raspberry pi, and a client application to enhance the animal-viewing experience for tourists at Rwanda's national parks. Previous efforts to track animal location have included the use of devices attached to animals [2], as well as computer vision and machine learning techniques applied to road cameras for the purpose of preserving animal safety. My approach has the potential to provide a more comprehensive and user-friendly solution for tourists and park management alike.

Through this research, we hope to contribute to the understanding of how machine learning, a raspberry pi, and a client application can be used to improve the animal-viewing experience for tourists at Rwanda's national parks. Our findings may also provide valuable insights for park management and policymakers seeking to enhance the overall tourism experience in the country.

1.2 Background and Motivation

Animal viewing is a major attraction for tourists visiting Rwanda's national parks, and the inability to see preferred animals can lead to frustration and disappointment. In December 2020, I experienced this firsthand during a trip to the Akagera National Park, where despite the efforts of our guide, we were unable to see a lion. This incident motivated me to explore the potential of using the knowledge acquired from the MSc. IoT-ECS to improve the animal-viewing experience for tourists at Rwanda's national parks.

Through this research, we aim to address the problem of tourists leaving national parks without seeing their preferred animals, and to provide a more comprehensive and user-friendly solution for tourists and park management alike.

1.3 Problem Statement

One of the main challenges faced by tourists in Rwanda's national parks is the frustration of not being able to see their preferred animals. This research aims to address this issue by proposing a system for detecting and recording the location of animals in the park. The system combines a machine-learning model (YoloV5) with a raspberry pi and a client application developed in React JS to classify images and show the location of animals on a map. While the full implementation of this system would require the deployment of multiple raspberry Pis throughout the park, we propose a one-component system as a proof of concept. With additional resources and time, we believe that this system could be scaled up and deployed on multiple devices to solve the problem on a larger scale.

1.4 Study Objectives

1.4.1 General Objective

The main objective of this research is to create a system that detects and records animal locations to facilitate tourists to search for their preferred animals.

1.4.2 Specific Objective

In this research, we implemented a single system that can produce the above objective.

However, with more resources, we can deploy this system to more devices in the park to tackle the problem in a broad way. Below are the specific objectives:

- Connect available cameras in the park with a Raspberry Pi. On the component used in this research we are using our camera.
- Train a model that detects animals (YoloV5) with an image dataset
- Compress the model so that It works on IoT devices (Raspberry pi, mobile phones ...) without losing too much of its performance.
- Send images taken by the cameras to the model, which will return the type of animal.
- Record the location, date, and time and send them to the cloud (Database) via an API.
- Design an API to fetch information.
- Design a dashboard that will map the received information for public use.

1.5 Scope of the Study

This research focused on 13 different animals found in the Rwanda National Parks and gorillas in the Volcanoes National Park. These animals include gorillas, elephants, buffalo, giraffes, zebras, leopards, hyenas, lions, impalas, chimpanzees, monkeys, crocodiles, and humans. The study was conducted using a single raspberry pi device and model, but in order to cover the entire national park, it will be necessary to deploy the model on multiple devices. In the future, I plan to expand the dataset by adding more images in order to improve the performance of the model.

1.6 Significance of the Research

This research has the potential to benefit the Rwandan tourism industry as a whole, by improving the services provided by national parks. By providing tourists with the location of animals, this research can help them save time and fuel that might otherwise be spent searching the park for a specific animal. Additionally, knowing the location of animals can help researchers understand why they are there and conduct further research. Overall, this research aims to enhance the animal-viewing experience for tourists at Rwanda's national parks, and may provide valuable insights for park management and policymakers.

1.7 Organization of the Study

The study is divided into six chapters. Chapter 1 provides an overview and general introduction of the study, while Chapter 2 offers a literature review to support ongoing research. The methodology of the research is discussed in Chapter 3, and Chapter 4 focuses on the analysis and design of the study. Chapter 5 presents the results of the analysis, and Chapter 6 provides the conclusion and recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

In this chapter, we will review the existing literature on animal location detection, with a focus on the work of previous researchers. We will analyze this literature and use it as a foundation for our current research. Our goal is to understand the state of the field and the available literature on the methodology used. Therefore, the literature will be divided into two categories: solutions developed and literature on the methods used in this research.

Animal detection is a growing research area, with numerous applications including the protection of animals from road accidents, the study of their movement patterns, and more. In this literature review, we will examine the various approaches that have been used to detect and track animals. I have found that many use computer vision and wireless sensor networks. Our goal is to identify the strengths and limitations of these approaches, and to identify areas for further research.

Computer vision for animal detection and safety

One approach to animal detection that has received significant attention is the use of computer vision techniques to detect animals approaching roads and provide a warning to drivers. For example, Jo et al. [3] describe the use of intelligent signs that light up to alert drivers to the presence of animals. This approach has been successful in reducing the number of road accidents involving animals in some countries.

Wireless sensor networks for animal detection and tracking

Another approach to animal detection and tracking involves the use of wireless sensor networks. In [4] the authors describe the use of GPS-based tracking with SMS alerts, in which a microcontroller collects data from sensors such as temperature and acceleration sensors, and sends this information to the user via SMS. This system can be used to monitor the conditions of animal and alert park officers if necessary.

In [5], the authors propose a hierarchical wild animal detection and notification system based on wireless sensor networks. This system uses detection nodes, relay nodes, and sink nodes to detect and report the presence of animals, and to warn drivers with warning signals.

Automated radio telemetry for animal tracking

Another approach to animal tracking is the use of automated radio telemetry, as described in [6], In this study, automated radio-telemetry receivers mounted on towers are used to track the activity and location of radio-collared animals around the clock. The data is transmitted wirelessly to a server in a laboratory, where it is made available for researchers. This approach has the advantage of being able to track animals 24/7, but it requires the use of radio collars, which may not be practical or ethical for all species.

2.1 Existing System

The existing system for identifying the location of animals for visitors at the tourist destination relies on the word-of-mouth and manual reporting system. The guides report the location of the animals they see to the reception, and the information is recorded on a blackboard.

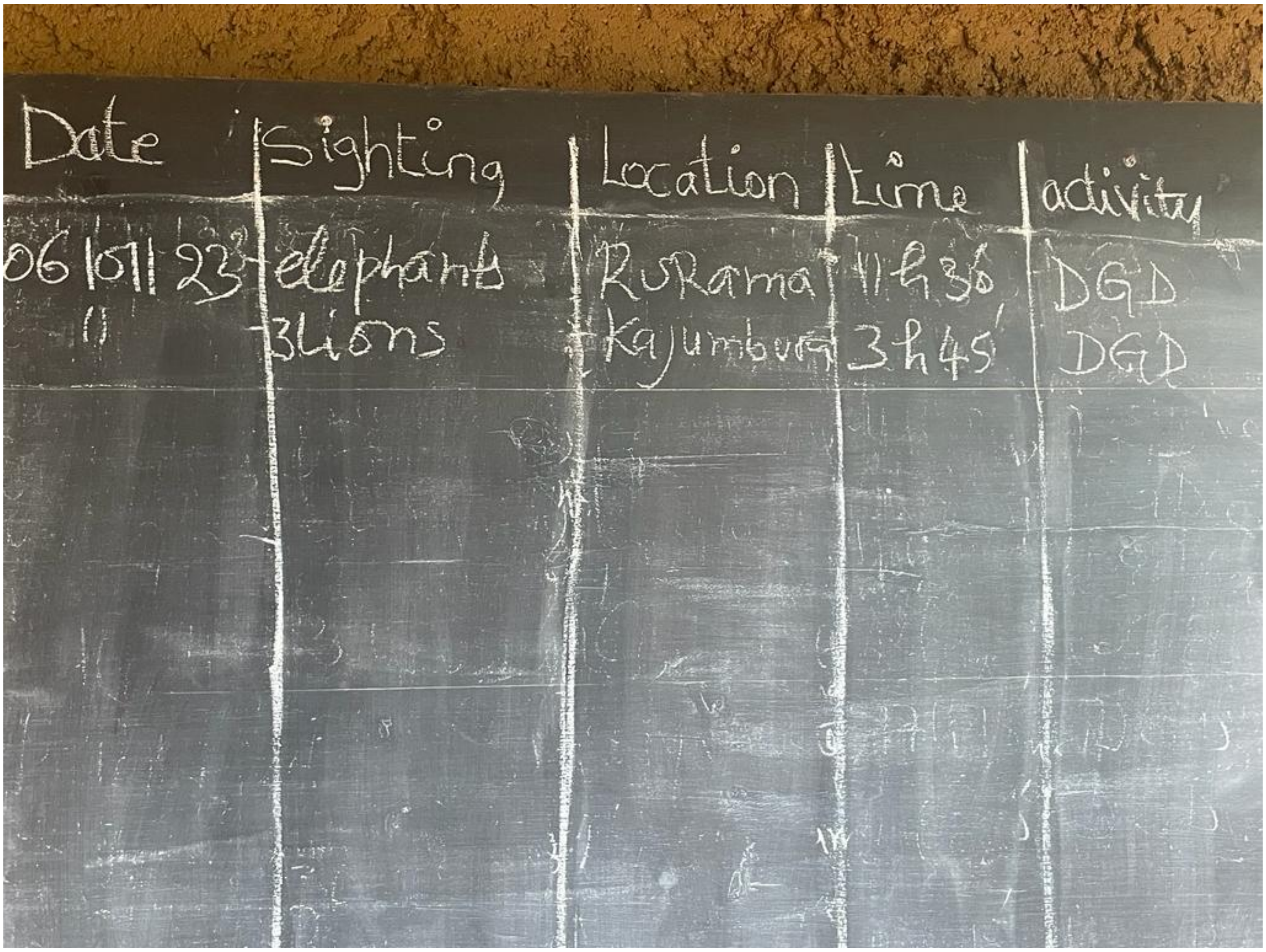

Figure 1 Recording of animal location seen by the guide (Current system from the parks)

Figure 1 depicts the sighting of two of the big five on 06/01/2023. The information recorded includes the location where the animals were spotted, the time of the sighting, and whether it was during the day or night.

Another approach is that different animals move at different times, so the guides know where to look depending on what time it is. For example, at 1 PM, many animals go to the lake to drink water. The guides might suggest that tourists go to the lake at that time to see what animals they can find.

This system has several drawbacks and limitations, including:

- Inaccuracy: The information on the blackboard may not be up-to-date or accurate, as it depends on the timely reporting of the guides and the manual recording of the information.
- Limited Access: Only visitors who go to the reception can access the information on the

blackboard, which may be inconvenient for those who are already at the destination.

- Inefficiency: The manual reporting process is time-consuming and prone to errors, leading to a less efficient system overall.
- Limited Visibility: The blackboard system does not provide a comprehensive overview of all the animals at the destination, and visitors may miss seeing some animals if they are not aware of their location.
- Lack of Interactivity: The blackboard system is passive and does not allow visitors to interact with the information, such as being able to filter or search for specific animals.

Given the limitations of the existing system, there is a clear need for a more efficient, accurate, and user-friendly system for tracking the location of animals at the tourist destination. This thesis aims to address these limitations by proposing a new system that leverages modern technology to provide visitors with real-time information on the location of animals at the destination.

Below is the literature review on the methodology used in this research. Starting with the Raspberry Pi, [9], this paper provides a review of the Raspberry Pi and its applications. The Raspberry Pi is an efficient and powerful minicomputer with dimensions approximately the size of a credit or debit card. Some of its benefits include:

- Inexpensive device that is easily available worldwide.
- Extensive peripheral support: The Raspberry Pi has 26 GPIO (General Purpose Input/Output) pins, which allows users to connect a greater number of external hardware devices. Additionally, it also supports almost all kinds of peripherals supported by Arduino
- Multiple sensors: it can support and connect multiple sensors simultaneously, enabling embedded system enthusiasts to develop innovative projects.
- Fast processor: compared to Arduino and other microcontroller modules, the Raspberry Pi has a faster processor.
- Portability: If a user attaches a display/monitor to it, it becomes a pocket-friendly computer.
- Supports all kinds of codes: this board supports codes of almost any language, including C, C#, C++, Ruby, Python, Java, and more

On the other hand, Raspberry Pi has some cons, namely:

- Missing Embedded Multi-Media Card (eMMC) Internal Storage: The major disadvantage of Raspberry Pi is that it does not have any internal memory storage, and the SD card works as internal storage for the device. Since the read and write, speed of the SD Card is much slower than that of eMMC (Embedded Multimedia Card); it increases the board's boot time.

- Missing Graphics Processor: As we all know, graphics processor plays an essential role in video editing, photo editing, and gaming. However, its competitors are providing an in-built GPU unit for a streamlined experience while running various graphics-built apps/software.

- Overheating: The board does not come with an integrated heat-sink or cooling fan. With the deployment of a powerful processor and multiple features, the board starts to heat up with average usage of 6-7 hours, mainly due to a smaller board size and no heat dissipation unit available onboard.

- Unable to Install Windows OS: As we all know, Windows is the most common operating system and is also very user-friendly for gaming, video editing, photo editing, and much more software. Due to this reason, Raspberry Pi faces tough competition with counter devices.

- Real-Time Clock (RTC): The board does not have an RTC with a backup battery.

With those disadvantages it why we are not saving anything on the raspberry pi, all the info is sent to the cloud database.

Ghael [9] gives some of raspberry pi applications:

- Home Automation System: This system can easily host home automation applications by interfacing relays, sensors, and lights with smartphones or computers. The operator can remotely operate the system.

- Zero-Powered Smartphone: Engineers can develop a homemade smartphone by assembling various electrical parts that are easily available.

- AI Assistant: This feature enables users to integrate common language voice commands using Google Assistant SDK and Google's Cloud Speech API.

Our own application will be part of the applications that uses Raspberry pi.

The YOLO (You Only Look Once) is a real-time object detection algorithm used in computer vision. Its purpose is to detect objects in images or video frames and classify them into predefined categories. The YOLO algorithm is known for its superior performance in complex and noisy data environments, availability, and ease of use with widely used programming languages like Python. In [8], Marko, Gordan, and Ljudevit compare different versions of YOLOv5 using 'Face Mask Detection' dataset and provide researchers with suggestions for selecting the best model for specific problem types. The YOLOv5 model includes 10 individual architectures named YOLOv5n, YOLOv5s, YOLOv5m, YOLOv5l, YOLOv5x, YOLOv5n6, YOLOv5s6, YOLOv5m6, YOLOv5l6, and YOLOv5x6 + TTA (Jocher, 2020a). Nevertheless, the most used are the first five. In this thesis, the most complex architecture YOLOv5x achieved the best results in the training subset, while models m and l performed slightly worse. The conclusion is that while complex models may have better accuracy in seen and unseen examples, it does not necessarily make them better, particularly for everyday use. In everyday applications, the time taken to process an input example is also important to consider, not just accuracy.

In this research I choose to use the YOLOv5s due to the following reasons:

- Speed: YOLOv5s is the fastest and most lightweight model in the YOLOv5 family. It can process images at a very high speed, making it suitable for real-time applications

- Memory efficiency: YOLOv5s requires less memory than the other variants, making it easier to run on resource-constrained devices such as mobile phones and embedded systems

- Accuracy: While YOLOv5s is not the most accurate model in the family, it still provides very good accuracy and can achieve high performance on a wide range of object detection tasks

- Versatility: YOLOv5s is a versatile model that can be used for a variety of object detection tasks, from detecting small objects in cluttered environments to detecting large objects in high-resolution images

Discussion and conclusion

Overall, the studies reviewed here demonstrate the potential of various approaches to animal detection and tracking, including computer vision, wireless sensor networks, and automated radio telemetry. While these approaches have their strengths and limitations, they offer promising solutions for enhancing our understanding of animal behavior and improving the protection and management of wildlife.

There are a number of areas where further research is needed. For example, more work is needed to optimize the performance and accuracy of computer vision models for animal detection, and to develop more effective methods for integrating these models into real-world systems. One of the best model available online is the YoloV5 and I choose it specifically for this project due to its accuracy.

In conclusion, the literature reviewed here highlights the potential of various approaches to animal detection and tracking, and identifies areas where further research is needed. My research brings a new way to use machine learning model and combining it with embedded computing and software development to tackle the animal location problem.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

In this chapter, we will explore the various techniques employed in the implementation of the "Animals Location Detection System Leveraging a Machine Learning Model and Raspberry Pi." This includes an examination of the necessary hardware and software components, the communication technology used within the system, and the types of data utilized.

Before discussing the technical details, let's talk about the methodology we intend to use. During site visits, we discovered that cameras have been deployed in different key zones across the national park. These cameras are used for the following purposes:

- Monitoring the safety of the animals
- Identifying if any animals have died
- Ensuring that tourists and guides are following the rules

Our methodology is to use these available cameras, as they are deployed in key areas across the park. We will connect the cameras to Raspberry Pis to gain access to them. Currently in the Akagera National Park are two roads that tourists can use to visit animals (lakeshore road and Hills road). On the lakeshore road they are between 60 – 80 camera and hills roads has about 40 cameras. These cameras do not cover all the area so used by tourists so with the help of guide and security we will identify missing area and add more. When the cameras are recording video, we will capture a frame as a picture and pass it to the model to identify the animal. If an animal is identified, we will send the animal type, date, time, and location to a cloud database. We intend to create a dashboard that is connected to the cloud database, which will watch for changes in the database and update itself accordingly.

This will give our system the ability to cover the most area of the national park, hence increasing the capability of locating animals. With all the nodes deployed across the national park, the end user will be able to view the real-time location of the animals.

3.2 Image Collection

In the research methodology, a significant part of the work involved collecting a dataset of images containing animals found in national parks in Rwanda. The dataset was used to train and test the YOLOv5 object detection model.

To collect the images, a combination of sources was used. Some images were obtained from publicly available datasets while others were captured in the field. The images captured include animals such as gorillas, elephants, buffalo, giraffes, zebras, leopards, hyenas, lions, impalas, chimpanzees, monkeys, crocodiles, and persons.

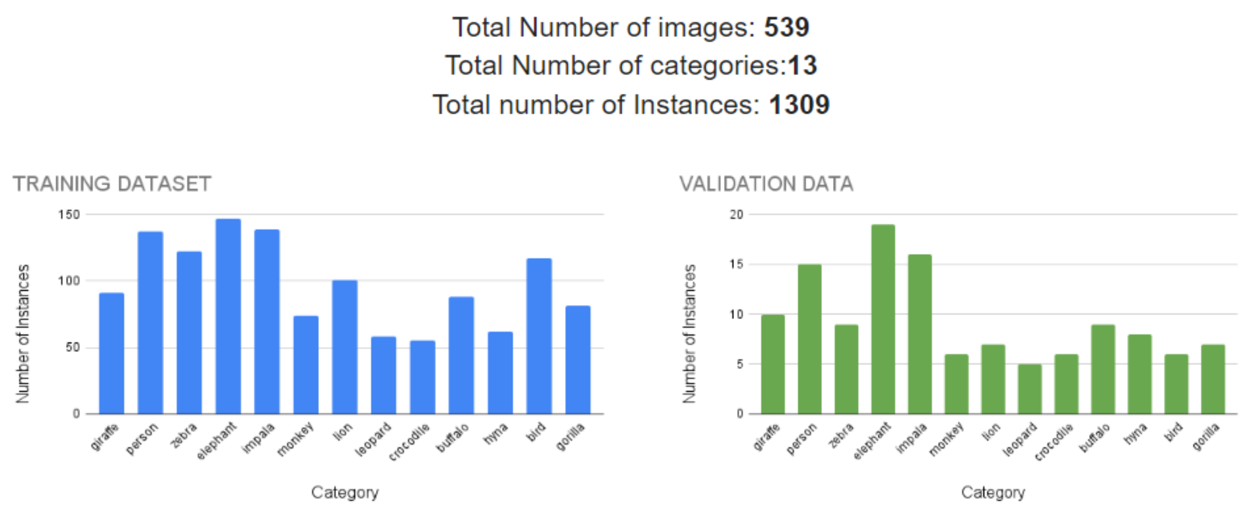

Figure 2 Image collection (Training)

After preprocessing and annotation, the dataset was divided into training, validation, and test sets. The training set was used to train the YOLOv5 model, the validation set was used to evaluate the performance of the model during training and the test set was used to evaluate the final performance of the model. This process is important to ensure that the model is generalizing well and that the accuracy on the test set is representative of the model's performance on unseen data.

To summarize, the research methodology involved the essential task of collecting images of animals present in national parks throughout Rwanda. The dataset was gathered from different sources, preprocessed and annotated, and subsequently divided into training, validation, and test sets.

3.3 Software

We have 3 parts of the software, an animal detection model (YoloV5), a software to read a camera and send images to the model, a software to send received data to the cloud, and an application to display them.

3.3.1 Animal Detection Model

In this research, the YOLOv5 (You Only Look Once version 5) object detection model is used to detect and classify animals in images captured by a Raspberry Pi. YOLOv5 is a real-time object detection model that is designed to detect and classify objects in images and videos. The model uses a single convolutional neural network (CNN) to predict the class and location of objects in an image

This algorithm divides images into a grid system. Each cell in the grid is responsible for detecting objects within itself. Yolo is the most famous object detection algorithm due to its speed and accuracy. Yolo has three main parts as illustrated by Figure 3.

- Model backbone: used to extract essential features from the given input image.
- Model neck: used to predict the class and bounding box
- Model head (predictor): used to generate feature pyramids that helps the model identify different things.

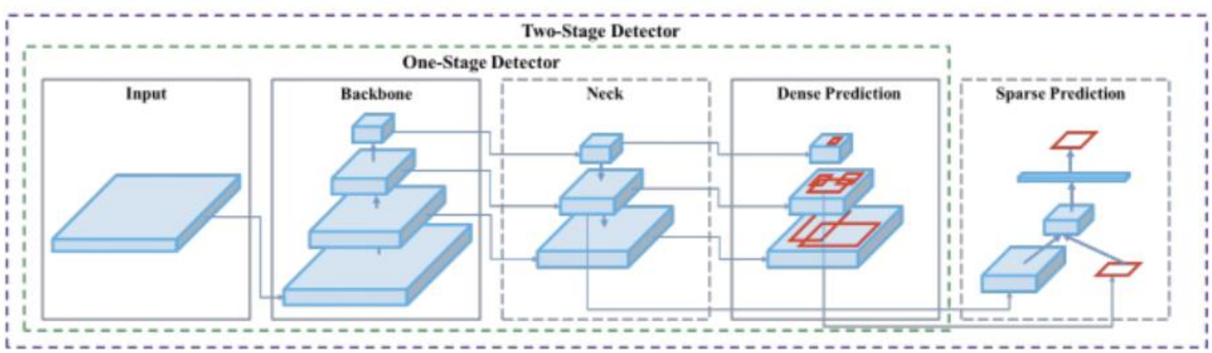

Figure 3 Yolo main parts

To train the YOLOv5 model, a dataset of images containing animals found in national parks in Rwanda was used. The dataset includes images of gorillas, elephants, buffalo, giraffes, zebras, leopards, hyenas, lions, impalas, chimpanzees, monkeys, crocodiles, and persons. The dataset was divided into training, validation and test sets. The model was trained using the training set and the performance was evaluated on the validation set. Once the model was considered accurate enough, it was tested on the test set.

3.3.2 Camera

In this research, a web camera was used to take pictures. To detect, capture, and send images we used Python code**.**

3.3.3 React JS Dashboard

In this research, a client application, developed using React JS, is used to display the location of animals on a map. The application is designed as a web-based dashboard that can be accessed by tourists visiting the national parks.

React JS is a JavaScript library that is widely used for building user interfaces, particularly web applications. One of its main advantages is that it allows developers to build reusable components that can be easily integrated into an application. This makes it an ideal choice for building the client application in this research.

The React JS application is built on top of the YOLOv5 object detection model, which is integrated with a Raspberry Pi. The Raspberry Pi captures images of animals and sends them to the YOLOv5 model for detection and classification, and the returned information is sent to the cloud. The detected animals' location information is then retrieved from the cloud database and sent to the React JS application, which uses the ArcGIS API for JavaScript to build maps and display layers showing the location of animals on a map. This allows tourists to know where to search when they are visiting animals.

The React JS application also allows users to filter the animals based on their class and view their locations on the map. It also provides additional information about the animals such as the time and date of detection, and the confidence level of the detection.

In summary, the React JS application is an essential part of this research as it allows tourists to view the location of animals on a map. The application is built using React JS, a JavaScript library that is widely used for building user interfaces. The ArcGIS API for JavaScript was used to build maps and display layers showing the location of animals.

3.4. Hardware

3.4.1 Raspberry PI

Raspberry Pi is a low cost, credit card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse [7]. Raspberry Pi boards are used for a variety of purposes. They are used in everything from home media centers and game consoles, to DIY cell phones, to universal remote controls for smart home appliances. They are also used for learning about hardware and software development. See Figure 4

In this research, we used it to host Yolov5 model and camera code. We used it also to send the captured information to the cloud.

In this research, we used Raspberry Pi 2. It has A 900MHz quad-core ARM Cortex-A7 CPU, along with the Raspberry Pi 1, it has 100 Base Ethernet, 4 USB ports, 40 GPIO pins, Full HDMI port, combined 3.5mm audio jack and composite video, Camera interface (CSI), Display interface (DSI), Micro SD card slot, VideoCore IV 3D graphics core

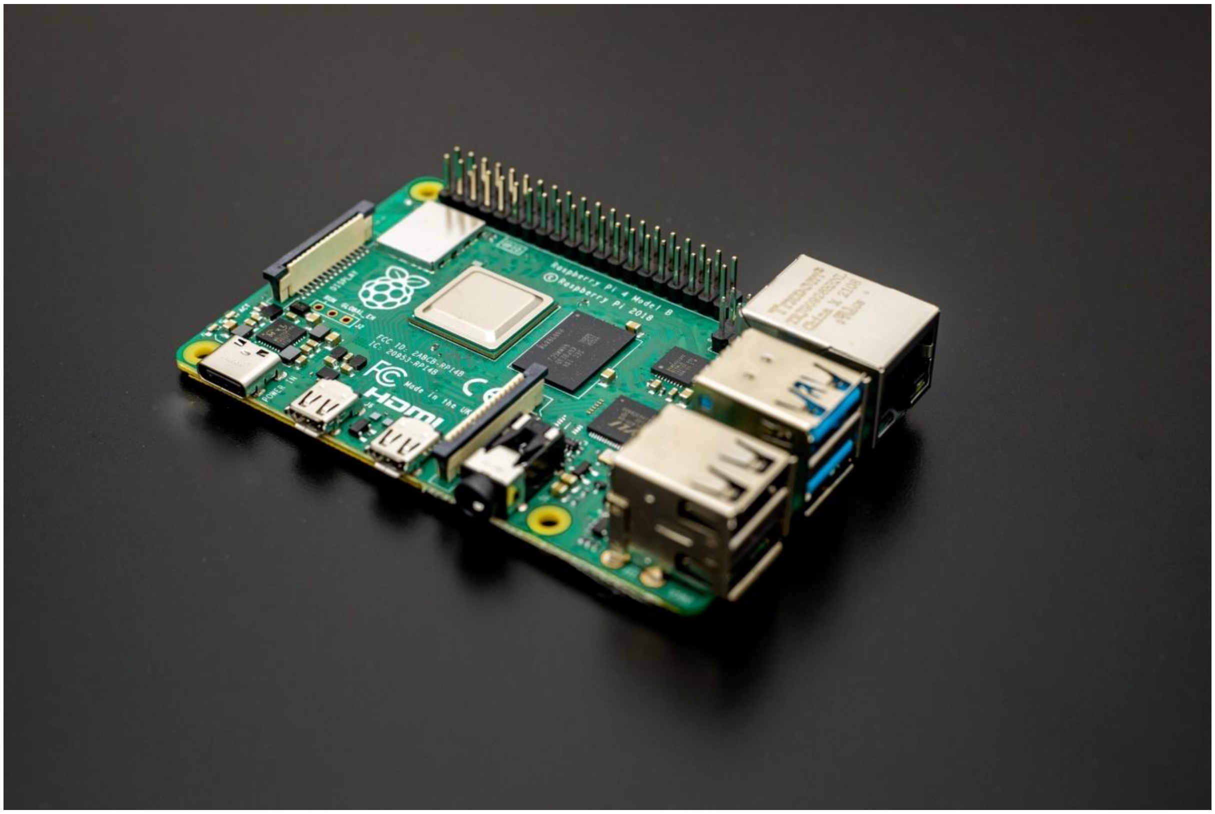

Figure 4 Raspberry Pi

3.4.2 CAMERA

In my research, the camera plays a vital role in recording animals round the clock. My plan is to utilize the cameras already installed in the national park's key areas, which safeguard the animals and enforce park rules. However, in case I face difficulties accessing these cameras or integrating with them, I will opt for a webcam. I have already employed a webcam in the project prototype.

A webcam is a basic video camera that captures still images and videos when connected to a computer. In our project, we connect it to the Raspberry Pi through USB to capture images used by a model to identify the type of animal captured. Python code is used to connect the webcam to the Raspberry Pi.

CHAPTER 4: SYSTEM ANALYSIS AND DESIGN

4.1 Introduction

In this chapter, we are going to see a detailed description of the proposed system and its design. We will also see the user interface and the flowchart of the whole system. We will briefly also talk on the existing system.

4.2 Proposed System

The "Animal Location Detection System Leveraging a Machine Learning Model and Raspberry Pi" utilizes a the already existing cameras that take videos for security purposes, and a machine learning object detection model (YoloV5) to classify images captured by the camera. These operations are performed on a Raspberry Pi device and the captured information is sent to the cloud for use in creating a client application for end-users. Figure 5shows the whole process and clearly indicates that we will more camera to answer to the question stated in the beginning of the thesis.

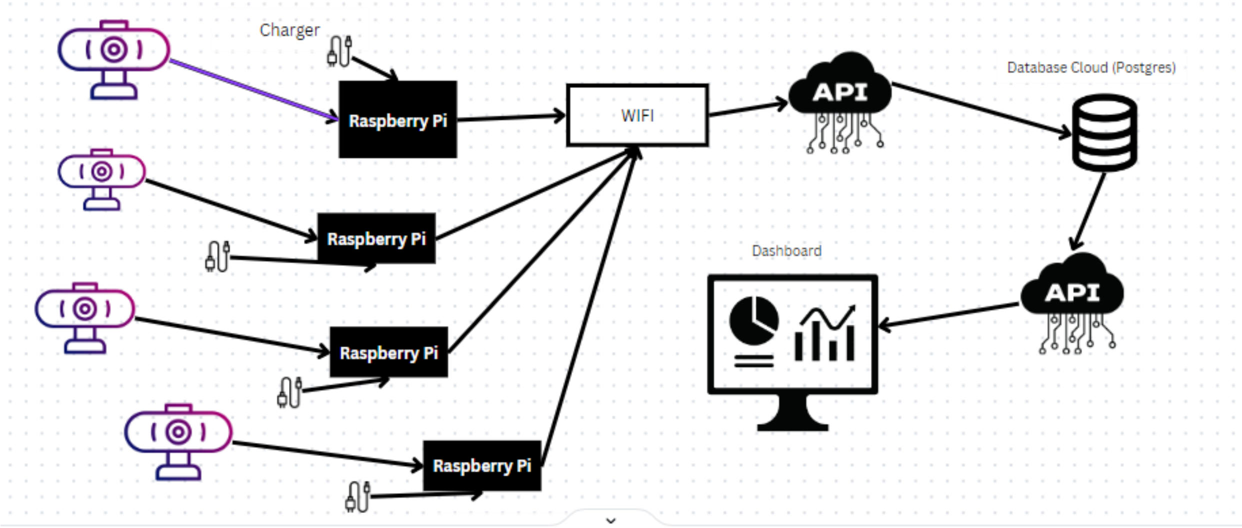

Figure 5 the proposed system

The main parts of the proposed are the following:

4.2.1 On Field Research and Model Training and Deployment

In this part, we visited the Akagera National Park, during my visit to Akagera National Park; we discovered that there were already cameras set up in various crucial locations. These cameras serve to track wildlife mortality and monitor guides and tourists to prevent any inappropriate actions. This is beneficial for us as we can utilize these existing cameras or deploy our projects in the same areas. Unfortunately, currently I am not authorized to examine the cameras and determine if they could help with my project. See Figure 6 for the step used on research and model training

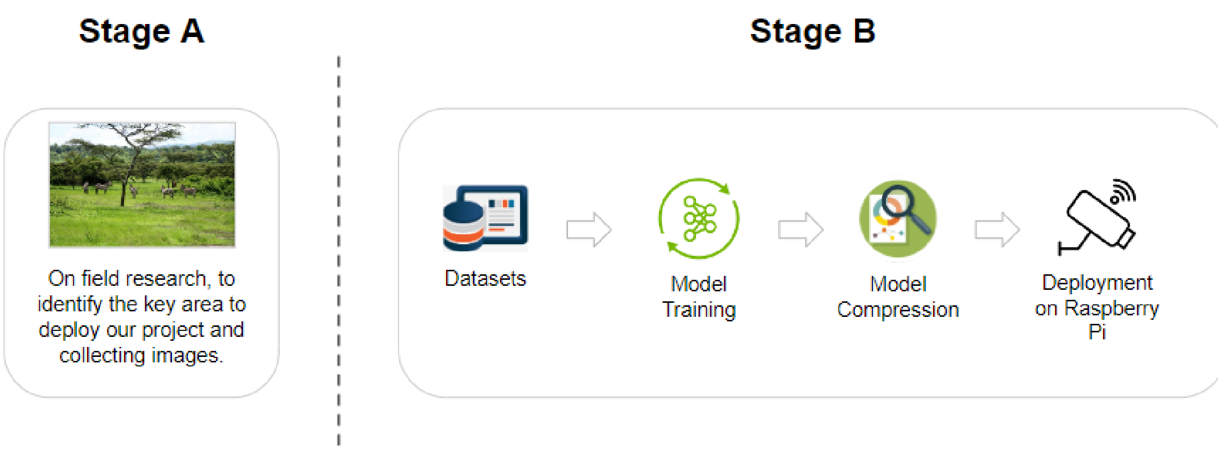

Figure 6 Proposed system part 1

The process was done along with the process of collecting animal images for model training and validation. Figure 7 shows the result of model training.

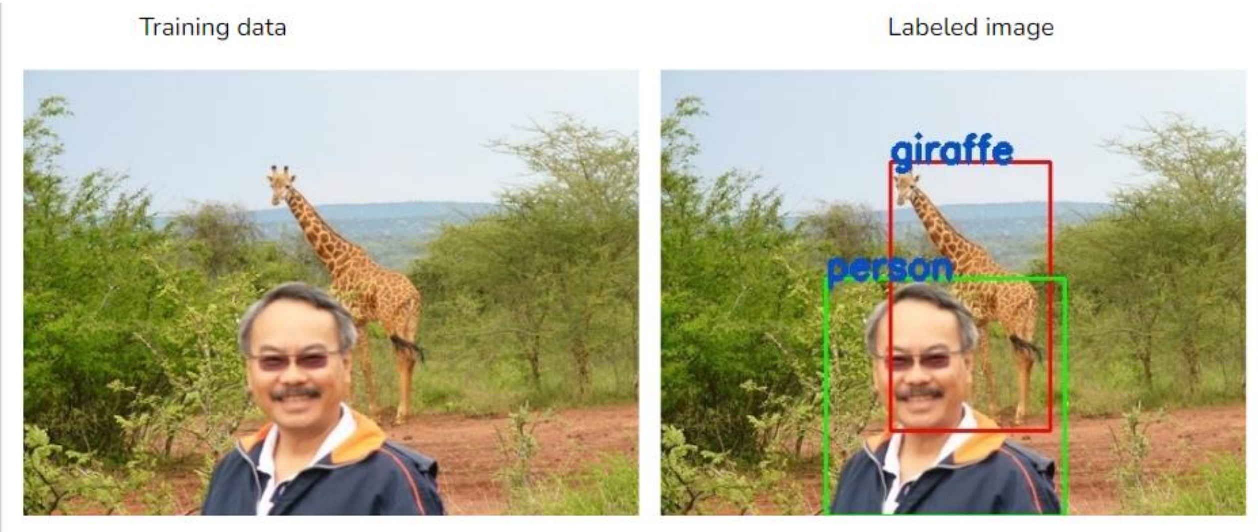

Figure 7 Image training and labeling

After this process, we go on the acquiring images process. The image is send to the created and deployed model.

4.3 Implementation

In this part, we are going to talk about the implementation. It involves model training, and the integration of hardware and software to enable communication. In the event that an animal is identified, the application will store its information on a cloud database (using PostgreSQL) through an API. Please refer to the system model provided below for more information.

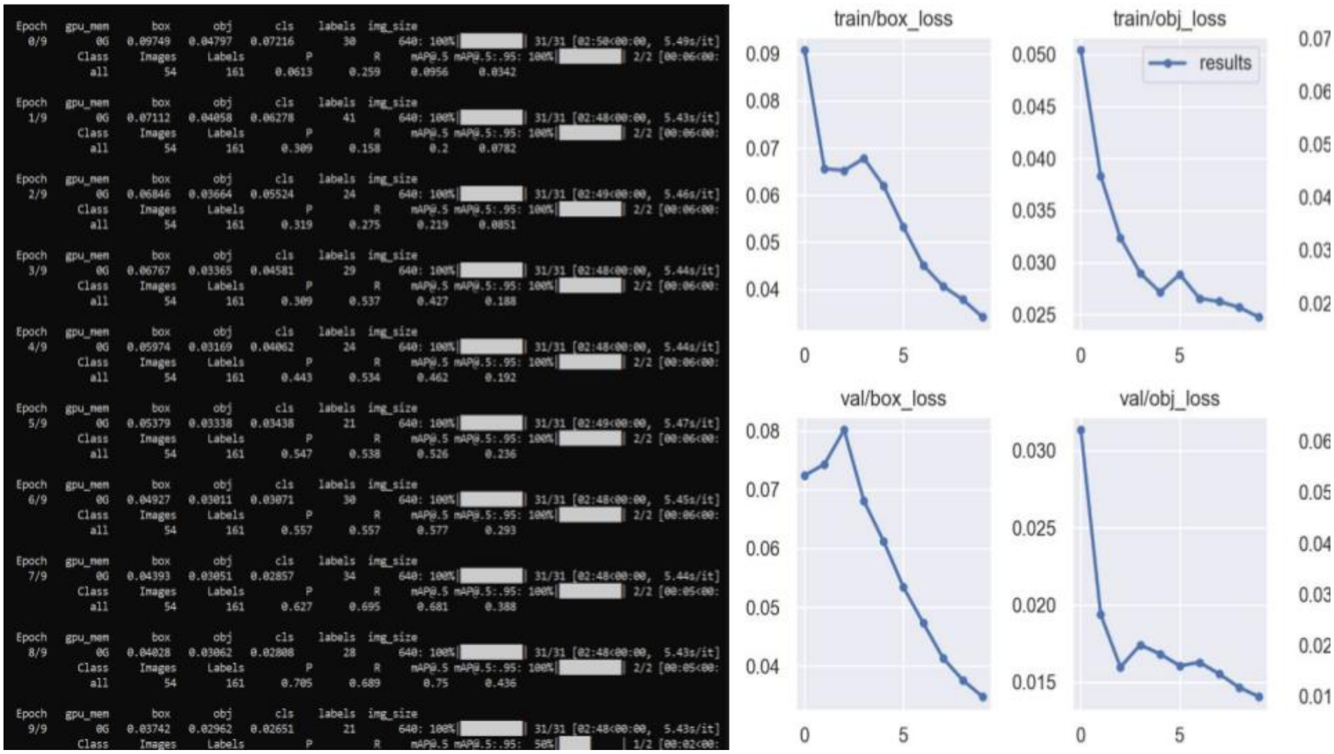

Figure 8 Model training

Figure 8 depicts a detailed process of model training on the YOLOv5 architecture. The training process involved using a large dataset of collected annotated images (animal images) to teach the model to accurately detect animal. During the training process, the model is repeatedly exposed to different examples of animal images and the corresponding ground-truth labels. This exposure enabled the model to learn how to differentiate animals with higher accuracy over time.

After the model training, below is the project block diagram followed with the flowchart. You can clearly see the whole process from the get go up to the end user product (Real time dashboard showing animal mapping and insight).

The flowchart presented in Figure 9 outlines the process of capturing images, passing them to the model for identification, and storing the animal's name along with the location and in a cloud database, if one is detected. This process will occur continuously at a frame rate that can range from 15 to 30 frames per second (fps), meaning that once the device is turned on, it will operate like a normal camera without interruption.

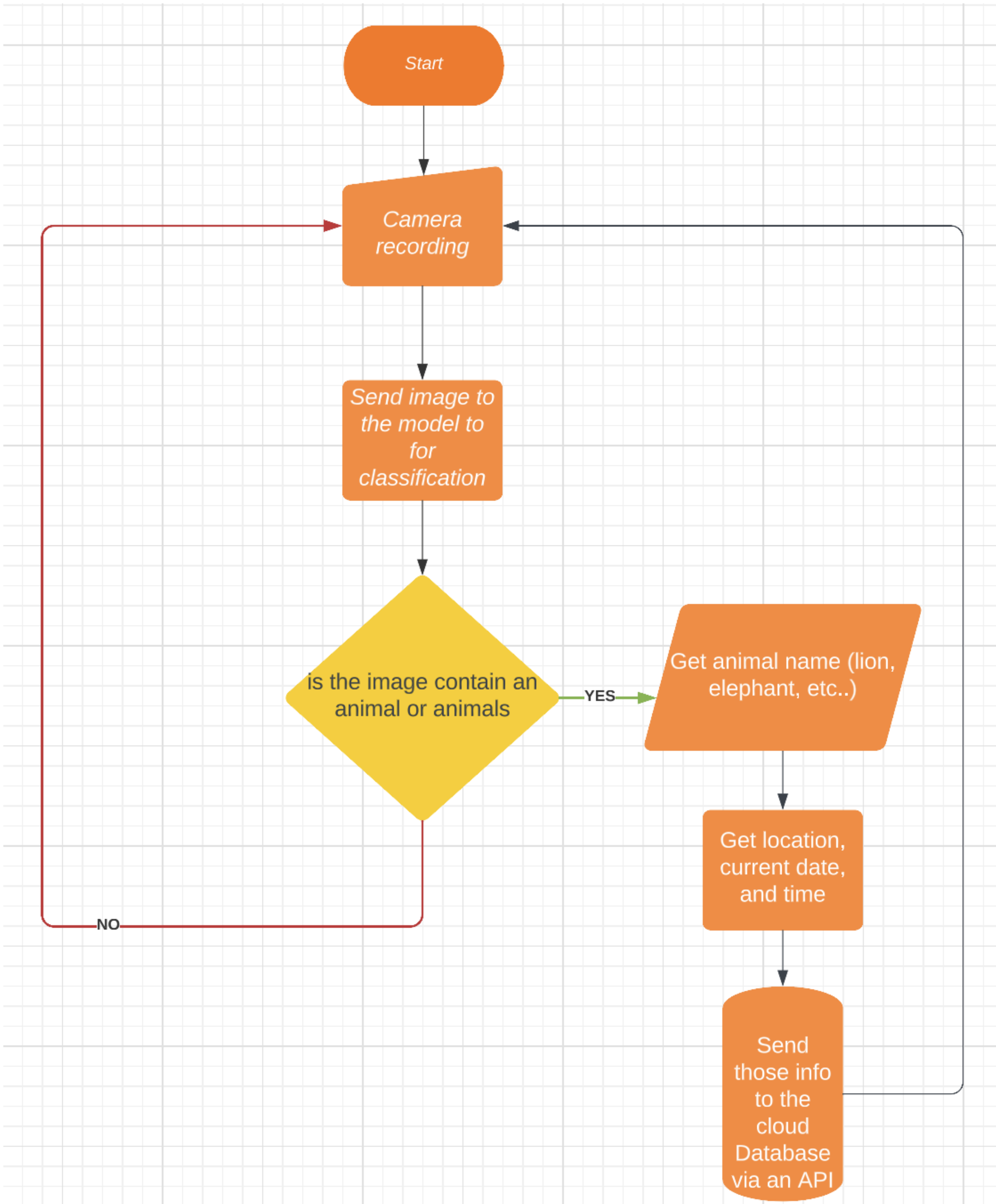

Figure 9Flowchart of the functionalities on the Raspberry Pie

Figure 10 Hardware Implementation

Figure 10 illustrates the hardware setup of the project, depicting how the various components, such as the Raspberry Pi, web camera, and charger, are packaged together.

CHAPTER 5: RESULTS OF ANALYSIS

In this chapter, we are going to present the results and interpretation of the project. Starting from the model results up to the dashboard.

5.1. Model Results and Predictions

The success of the model training process is a significant milestone in this study. The model was trained using a large dataset of images of various animals found in the national parks of Rwanda. The model was able to detect all the animal categories that were specified with a high accuracy of 94.4% percentage, which indicates the effectiveness of the algorithm used. The ability of the model to confidently give a name of the animal located on one image or identify many animals located on one image at the same time is a major achievement, as this capability is a key in showing the real time detected animals and hence help the tourists to know where animals are. The accuracy of the model was verified using a separate test dataset, which confirmed the robustness and effectiveness of the algorithm.

In the Figure 11, you can see the performance results for all animals, as well as for each category. The performance may vary, and this is mostly due to the images used and the fact that the model might work differently. Figure 12 shows the model mean average precision and recall. It also shows sample predictions. On the right side, you can clearly see the animal predicted and their category.

Class	Images	Instances	mAP@.5
all	54	161	0.944
giraffe	54	11	0.971
person	54	14	0.995
zebra	54	15	0.995
elephant	54	17	0.995
impala	54	18	0.961
lion	54	11	0.815
leopard	54	4	0.995
crocodile	54	5	0.995
buffalo	54	12	0.984
hyna	54	6	0.885
bird	54	26	0.787
gorilla	54	22	0.953

Figure 11 Model performance results

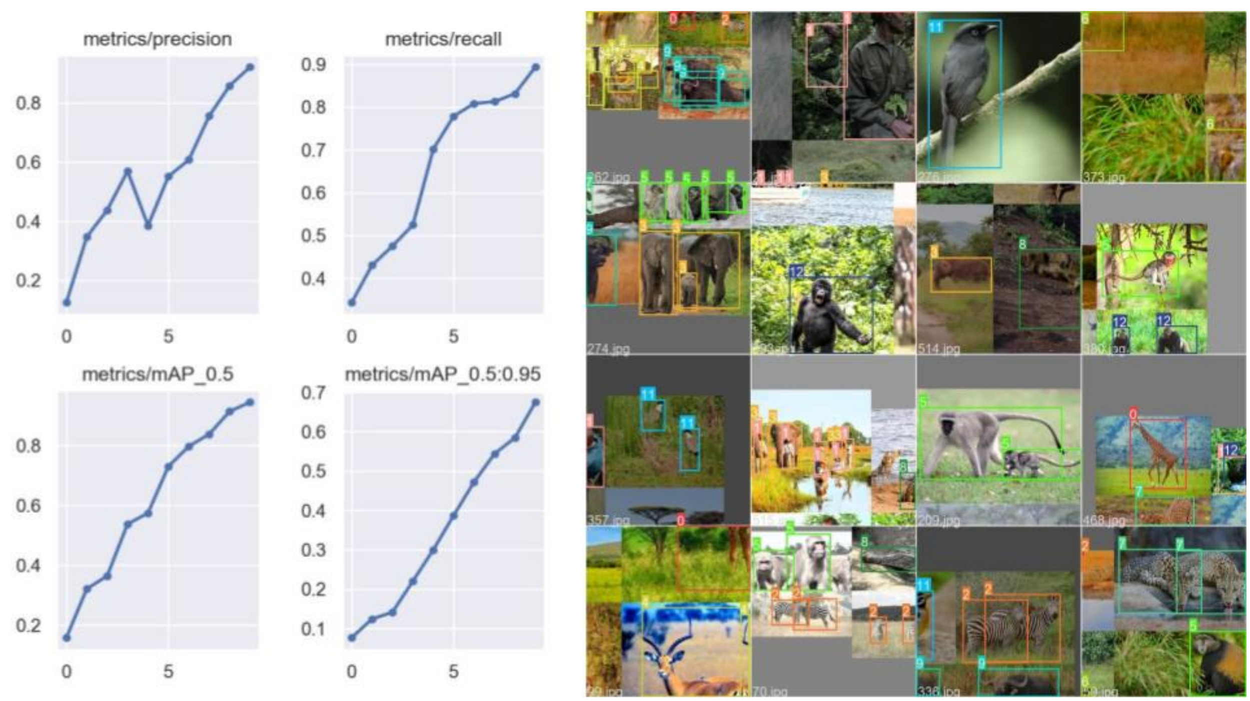

Figure 12 Model Metrics

After the model training, the next step was to set up on a raspberry pi. This was also done successfully.

5.1. Dashboard Animal Mapping and Insight

After completing the successful training of the animal detection model and installing it on the Raspberry Pi, the next step in the project was to develop a dashboard that would display the animals detected by the model. In addition to saving the name of the animal, location, date, and time when it was detected, we also saved the captured image in a base64 string format. This enabled the feature of displaying the image on the dashboard, providing a visual representation of the animal detected. The dashboard was designed to be simple and intuitive, allowing users to easily view and access the information displayed. The results images provided a clear demonstration of the dashboard's capabilities and how it can be used to identify animals in a given area and enable end users to access them before visiting parks. Figure 13 shows the dashboard and a popup of one of the captured animal.

The image clearly shows the time, date, and location of the animal captured. And this is the end goal of the research

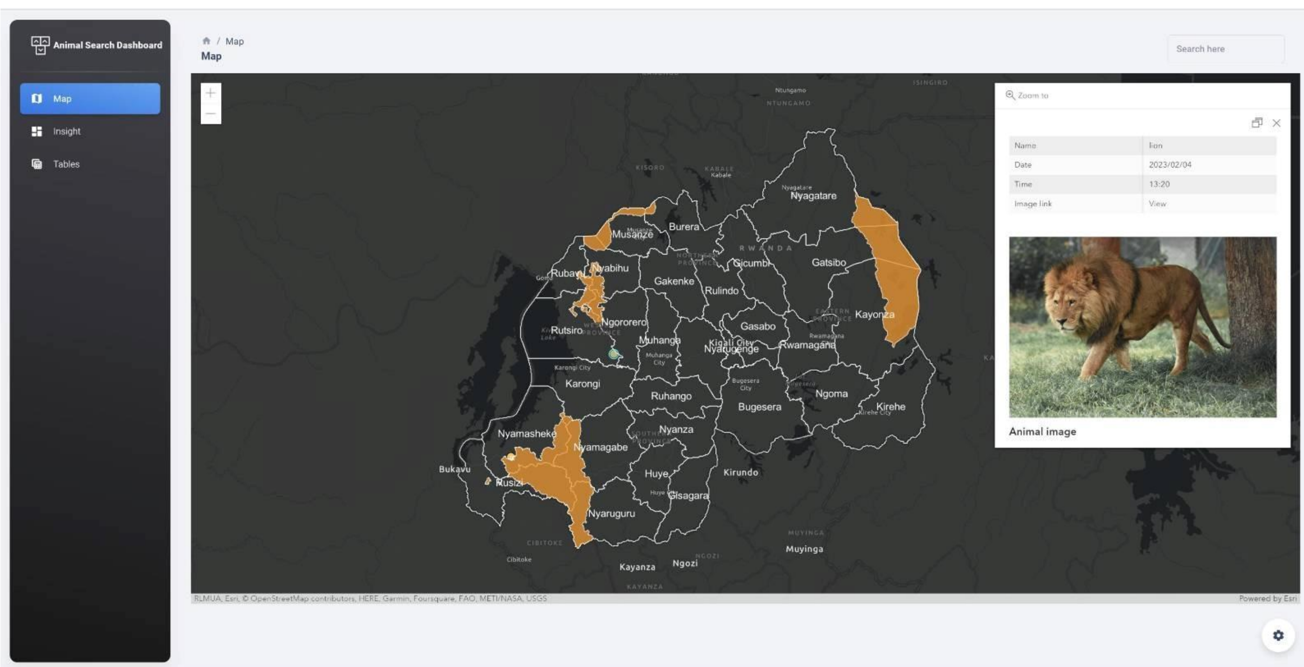

Figure 13 The look of the dashboard

In order to make the dashboard more user-friendly and informative, a layer of all the

Rwandan national parks and district boundaries was added. This additional layer provided context for the location of animal sightings and made the dashboard more visually appealing. To further enhance the user experience, a popup Figure 14 was included to display detailed information about each animal sighting. The popup included the name of the animal detected, the date and time of the sighting, and a picture taken at the location. This allowed the user to easily gather important information about each animal sighting without having to navigate through multiple pages. The popup also included a larger version of the image captured, allowing for a more detailed view of the animal and the surrounding area. Overall, the inclusion of these features significantly improved the usability and effectiveness of the dashboard.

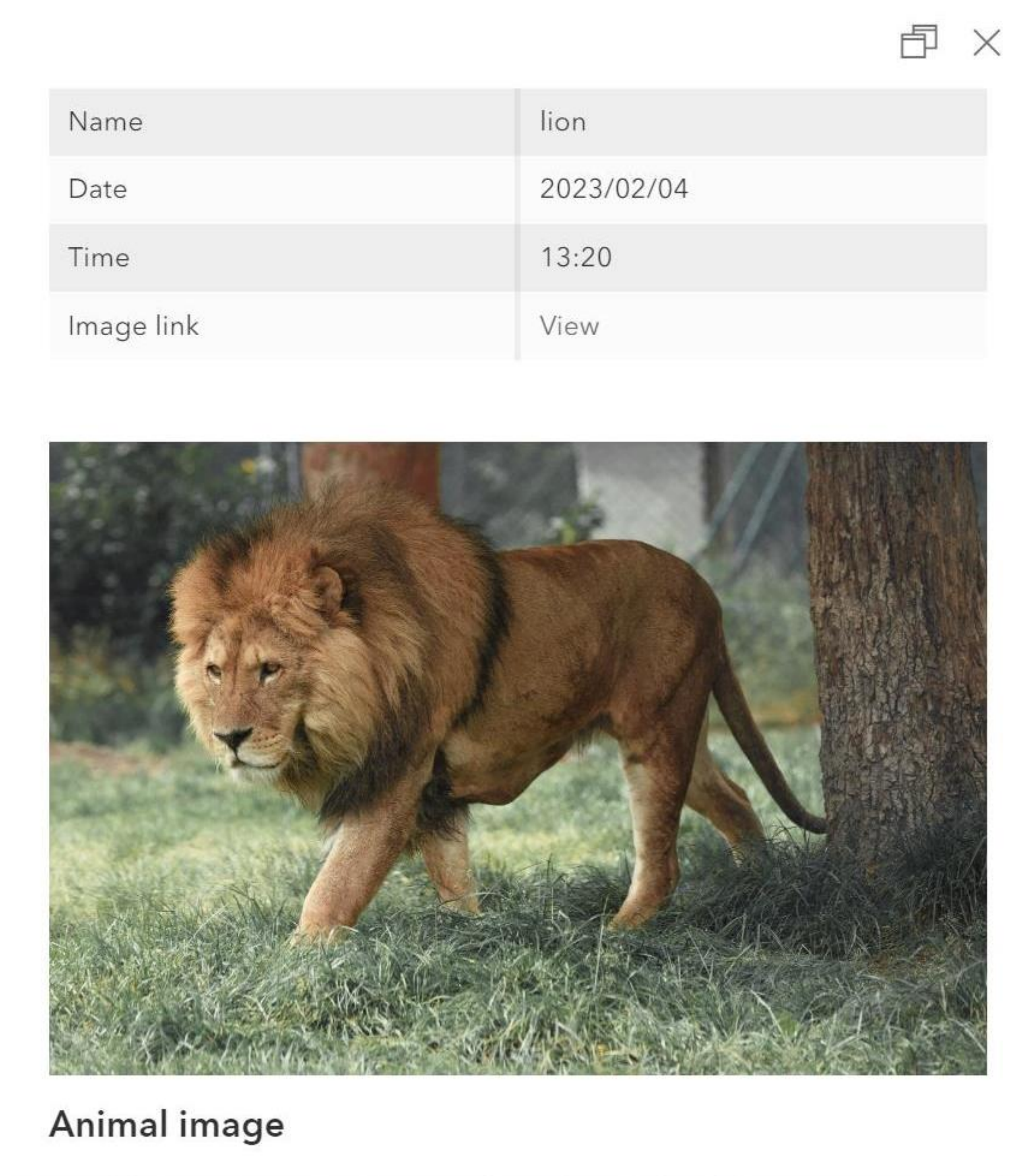

Figure 14 The popup with animal information

The dashboard developed also has an insights page that serves to increase the information that end-users can get from the product. One of the insights that were included in the dashboard was the Big 5 category, which is a group of animals that most people want to see and are considered the big animals in terms of character (Lion, Buffalo, Elephant, Rhino, and Leopard) in the Akagera National Park. The insight shows the time and month when the Big 5 are seen most frequently.

This can be useful for tourists to plan their visit accordingly. However, it is important to note that due to the limited information available, the stats presented in Figure 15 may be misleading, although the functionality works as intended. By including such insights, the dashboard can provide more value to users beyond the real-time animal detection feature.

Big 5 and their Peak hours/month BIG 5

NAME	PEAK HOUR	PEAK MONTH
Lion	11 AM	6
Buffalo	1 PM	6
Elephant	1 PM	6
Rhino	10 AM	2
Leopard	1 PM	12

Figure 15 Insight figure

Figure 16 shows an insight of the most searched animals on the platform. This information is crucial not only for the end-users but also for the park authorities and guides. The data can help them to understand which animals are attracting more interest among visitors and can also help them to create targeted marketing campaigns to promote lesser-known animals or species that are equally interesting. The most searched animals may not only include the big 5, so it is essential to have this information to plan effective marketing strategies. With this information, parks can tailor their conservation and educational programs to the interests of the visitors, creating a more engaging and informative experience. Additionally, the data can also be used to understand which animals may need additional conservation efforts or attention due to their popularity.

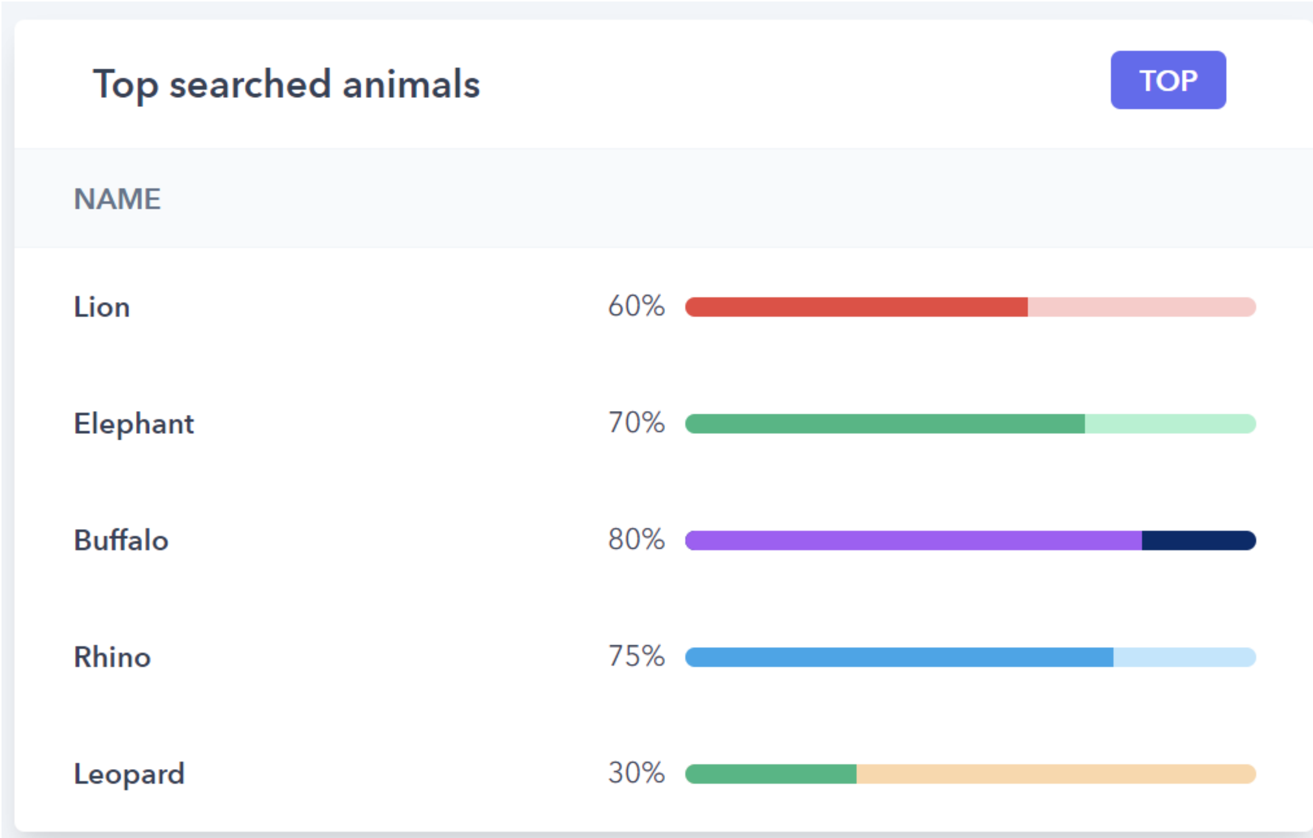

Figure 16 Insight figure 2

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, this thesis has demonstrated that by combining embedded system skills and machine learning, we have developed a cost-effective and efficient system for helping tourists to know where animals are located and plan ahead. As the dashboard showed, we can see the location of animals and even view the pictures. The use of machine learning model (Yolov5) has also shown to be effective in training models to identify different types of animals with high accuracy. It is worthy to clarify that in this thesis we talked about one system located at one location. However, the success of this project in a big national park rely on the deployment of the system to many key areas of the park. With Akagera National Park I already know that they are, cameras deployed there used to see the safety of the animals and control the use of the park.

In addition, the system presented in this thesis has the potential to make significant contributions to the fields of wildlife conservation and animal behavior research. By providing an improved way to monitor and study animal populations in their natural habitats, the system can help us gain a better understanding of their behavior and support our efforts to protect and conserve these important species.

6.2 Recommendation

As mentioned earlier, the project's success heavily depends on deploying the system in all of the park's key areas. While some areas are already identified based on the existing security cameras, covering a large area of the park requires working with guides and security personnel to identify additional areas and deploy the system. To achieve this, the system must be reliable and effective, while addressing any practical or ethical concerns that may arise. It is important to ensure that the system does not negatively affect the animals or their habitats, and that any data collected is used responsibly and ethically. The development of such a system could provide valuable insights into animal behavior and population dynamics in real-time, which could help to better protect and manage important species.

Based on the findings of this study, I highly recommend that other researchers explore the handover process between cameras in areas where the view of animals is interrupted due to camera placement or terrain. This could be accomplished by using machine learning algorithms to identify the areas where camera handovers occur, as well as implementing predictive models to improve the effectiveness of camera handovers. These efforts could lead to more comprehensive animal monitoring and enhance the overall visitor experience in national parks.

Additionally, I recommend further research into understanding animal behaviors and habitat preferences to improve the accuracy of location tracking systems. Specifically, researchers could study the factors that influence where animals are located the most and why, such as food availability, terrain, and vegetation cover. By gaining a better understanding of these factors, researchers can develop more effective monitoring strategies that consider the behavior and ecology of the animals, which can ultimately lead to more successful conservation efforts.

REFERENCES

[1] RDB (Rwanda Development Board), "Tourism Overview" https://rdb.rw/investment-opportunities/invest-in-tourism/. (Accessed October 02, 2022).

[2] Priyadharsini. S, Renukasri.V,Sneha. R, Sowmiya. P. K, Swaathi. K., Wildlife Animal Tracking System using GPS and GSM. Published by https://www.ijert.org/, Volume 8, Issue 17. 2020.

[3] Y. Jo, J. Choi, and I. Jung, “Traffic information acquisition system with ultrasonic sensors in wireless sensor networks,” *Int. J. Distrib. Sens. Networks*, vol. 2014, 2014, doi: 10.1155/2014/961073.

[4] Bhatt, Er Nabin & Rai, Samundra & Bastakoti, Janak & K.C., Saban. (2019). GPS based Animal Tracking with SMS Alert.

[5] Antônio, W. H. S. et al. (2019) ‘A Proposal of an Animal Detection System Using Machine Learning’, Applied Artificial Intelligence. Taylor & Francis, 33(13), pp. 1093–1106. doi: 10.1080/08839514.2019.1673993.

[6] Kays, Roland & Tilak, Sameer & Crofoot, Margaret & Fountain, Tony & Obando, Daniel & Ortega, Alejandro & Kümmeth, Franz & Mandel, Jamie & Swenson, Jr, George & Lambert, Thomas & Hirsch, Ben & Wikelski, Martin. (2011). Tracking Animal Location and Activity with an Automated Radio Telemetry System in a Tropical Rainforest. The Computer Journal. 54. 1931-1948. 10.1093/comjnl/bxr072.

[7] Raspberry PI Foundation" What is a Raspberry Pi https://www.raspberrypi.org/help/what-%20is-a-raspberry-pi//. (Accessed January 20, 2023).

[8] Horvat, Marko & Jelečević, Ljudevit & Gledec, Gordan. (2022). A comparative study of YOLOv5 models performance for image localization and classification.

[9] Ghael, Hirak. (2020). A Review Paper on Raspberry Pi and its Applications. 10.35629/5252-0212225227.

[10] Harshada Chaudhari, “Raspberry Pi Technology: A Review”, Volume 2, Issue 3, 2015

[11] Shrutik Katchiiand Pritish Sachdeva, “A Review Paper on Raspberry Pi”, Vol.4, No.6,Dec 2014

[12] Savvides, A., Han, C.-C. and Strivastava, M.B. (2001) Dynamic Fine-Grained Localization in Ad-hoc Networks ofSensors. Proc. 7th Annual Int. Conf. Mobile Computing and Networking, New York, NY, USA, MobiCom ’01, pp. 166–179.ACM

[13] M.Bathula, M. Ramezanali, I. Pradhan, N. Patel, J. Gotschall, and N. Sridhar, “A sensor network system for measuring traffic in short-term construction work zones,” Distributed Computing in Sensor Systems, vol. 5516, no. 1, pp. 216–230, 2009

[14] Mech, L. & Barber-Meyer, Shannon. (2002). A CRITIQUE OF WILDLIFE RADIO-TRACKING AND ITS USE IN NATIONAL PARKS. U.S. National Park Service Report. 1-78.

[15] S, Dhanalakshmi & M, Archanaa & P, Arun & S, Sathish. (2021). EMI Tracking System. International Research Journal on Advanced Science Hub. 3. 34-37. 10.47392/irjash.2021.058.

[16] Hofstra, Gerben & Roelofs, J.B. & Rutter, Steven & Van Erp-van der Kooij, Elaine & Vlieg, Jakob. (2022). Mapping Welfare: Location Determining Techniques and Their Potential for Managing Cattle Welfare—A Review. Dairy. 3. 776-788. 10.3390/dairy3040053.

[17] Harel, Roi & Alavi, Shauhin & Ashbury, Alison & Aurisano, Jillian & Berger-Wolf, Tanya & Davis, Grace & Hirsch, Ben & Kalbitzer, Urs & Kays, Roland & Mclean, Kevin & Núñez, Chase & Vining, Alexander & Walton, Zea & Havmøller, Rasmus & Crofoot, Margaret. (2022). Life in 2.5D: Animal Movement in the Trees. Frontiers in Ecology and Evolution. 10. 10.3389/fevo.2022.801850.

[18] W. W., and R. D. Lord, Jr. 1963. A radio-tracking system for wild animals. J. Wldl. Manage. 27:9-24