

# **VIRTUAL FENCE TO PROTECT LIVESTOCK**

## **A Project Report Phase – II**

Submitted in partial fulfillment of the requirements for the award of  
Bachelor of Engineering degree in Electronics and Communication Engineering

by

KANIKA M S ( 39130206 )  
NEHA V ( 39130323 )



**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING  
SCHOOL OF ELECTRICAL AND ELECTRONICS**

# **SATHYABAMA**

**INSTITUTE OF SCIENCE AND TECHNOLOGY  
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC**

**JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

**APRIL - 2023**



# **SATHYABAMA**

INSTITUTE OF SCIENCE AND TECHNOLOGY  
(DEEMED TO BE UNIVERSITY)

Accredited with "A" grade by NAAC  
Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119  
[www.sathyabama.ac.in](http://www.sathyabama.ac.in)

---

**DEPARTMENT OF ELECTRONICS AND COMMUNICAITON ENGINEERING**

## **BONAFIDE CERTIFICATE**

This is to certify that this Project Report is the bonafide work of KANIKA M S (39130206), NEHA V (39130323), who carried out the project entitled "**VIRTUAL FENCE TO PROTECT LIVESTOCK**" under our supervision from November 2022 to April 2023.

**Internal Guide**

**Dr. R .M . JOANY, M.E., Ph.D.,**

**Head of the Department**

**Dr. T. RAVI, M.E., Ph.D.,**

---

Submitted for Viva voce Examination held on 20/04/2023

**Internal Examiner**

**External Examiner**

## DECLARATION

We KANIKA M S (39130206), NEHA V (39130323) hereby declare that the project entitled “**VIRTUAL FENCE TO PROTECT LIVESTOCK**” done by us under the guidance of **Dr.R.M.JOANY, M.E.,Ph.D.**, Associate Professor, Department of Electronics and Communication Engineering, Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

**DATE:** 20/04/2023

**PLACE:** Chennai

1. Kanika M S

2. Neha V

**SIGNATURE OF THE CANDIDATES**

## ACKNOWLEDGEMENT

We are pleased to acknowledge our sincere thanks to **Board of Management of SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks to **Dr. N. M. Nandhitha, M.E., Ph.D., Professor & Dean, School of Electrical and Electronics** and **Dr. T. Ravi, Ph.D., Professor & Head, Department of Electronics and Communication Engineering** for providing us necessary support and details at the right time during the progressive reviews.

We would like to express our sincere and deep sense of gratitude to our **Project Guide Dr. R. M. Joany, M.E., Ph.D.**, for her valuable guidance, suggestions and constant encouragement paved way to do the project work.

We wish to express our thanks to all Teaching and Non-teaching staff members of the **Department of Electronics and Communication Engineering** who were helpful in many ways for the completion of project.

## **ABSTRACT**

This project involves the development of a virtual fence system to safeguard livestock from straying into fields and causing damage. Currently, farmers spend a lot of time and money manually patrolling their fields to prevent such invasions. The objective of this project is to reduce the need for manual intervention by implementing a system that uses technology to monitor the field and keep livestock within the designated boundaries. The proposed system involves the installation of nodes in the field that are equipped with Arduino Uno, PIR sensor, vibration sensors, sound generating devices, and Bluetooth module. Livestock crossing the boundary of the farm field can be detected using the PIR sensor, while the vibration sensor can detect any movement caused by the livestock. These sensors' responses can be displayed on an LCD screen, and farmers can be alerted to the presence of livestock using a smartphone app with GPS capabilities. The system can generate audio warnings and virtual barriers to keep the livestock within the designated area. The virtual fence can be designed in any geometrical shape, providing flexibility to farmers.

# TABLE OF CONTENTS

| CHAPTER No. | TITLE                                               | PAGE No. |
|-------------|-----------------------------------------------------|----------|
|             | <b>ABSTRACT</b>                                     | v        |
|             | <b>LIST OF FIGURES</b>                              | vii      |
| 1           | <b>INTRODUCTION</b>                                 | 1        |
|             | 1.1 Background                                      | 1        |
|             | 1.2 Description of the Project                      | 2        |
|             | 1.3 Problem Statement                               | 3        |
|             | 1.4 Project Objective                               | 5        |
|             | 1.4.1 General Objective                             | 5        |
|             | 1.4.2 Specific Objective                            | 6        |
| 2           | <b>LITERATURE SURVEY</b>                            | 7        |
|             | 2.1 Inference from Literature survey                | 7        |
|             | 2.2 Open problems in existing system                | 8        |
| 3           | <b>AIM AND SCOPE OF THE PROJECT</b>                 | 10       |
|             | 3.1 Aim of the project                              | 10       |
|             | 3.2 Scope of the project                            | 10       |
| 4           | <b>SYSTEM DESIGN</b>                                | 12       |
|             | 4.1 Existing System                                 | 12       |
|             | 4.2 Proposed System                                 | 14       |
|             | 4.3 Difference between Existing and Proposed system | 16       |
| 5           | <b>REQUIREMENT ANALYSIS</b>                         | 19       |
|             | 5.1 Software Requirements                           | 19       |
|             | 5.1.1 Google colab                                  | 19       |

|   |       |                               |    |
|---|-------|-------------------------------|----|
|   | 5.1.2 | Libraries for GPS processing  | 20 |
|   | 5.1.3 | Python                        | 20 |
|   | 5.1.4 | Geopandas                     | 21 |
|   | 5.1.5 | GPS trajectory dataset        | 23 |
|   | 5.1.6 | Pushbullet API                | 23 |
|   | 5.2   | System architecture           | 24 |
|   | 5.3   | Software design               | 27 |
|   | 5.4   | System use case               | 29 |
|   | 5.5   | System testing                | 30 |
| 6 |       | <b>RESULT AND DISCUSSION</b>  | 33 |
|   | 6.1   | Result                        | 33 |
|   | 6.2   | Discussion                    | 34 |
|   | 6.3   | Advantages                    | 35 |
|   | 6.4   | Limitations                   | 40 |
| 7 |       | <b>SUMMARY AND CONCLUSION</b> | 37 |
|   | 7.1   | Conclusion                    | 37 |
|   | 7.2   | Future work                   | 37 |
|   | 7.3   | Research issues               | 39 |
|   | 7.4   | Implementation issues         | 40 |
|   |       | <b>REFERENCES</b>             | 42 |
|   |       | <b>APPENDIX</b>               |    |
|   | A.    | <b>SOURCE CODE</b>            | 43 |
|   | B.    | <b>SCREENSHOTS</b>            | 46 |
|   | C.    | <b>RESEARCH PAPER</b>         | 48 |

## LIST OF FIGURES

| FIGURE. No. | FIGURE NAME                                        | PAGE No. |
|-------------|----------------------------------------------------|----------|
| Fig 1.1     | Virtual boundary                                   | 2        |
| Fig 1.2     | Fencing using GPS                                  | 2        |
| Fig 4.1     | Block diagram for first warning zone               | 12       |
| Fig 4.2     | Transmitting and receiving circuit                 | 13       |
| Fig 4.3     | Block diagram for second warning zone              | 14       |
| Fig 4.4     | Block diagram of virtual fence                     | 16       |
| Fig 5.1     | Logo of google colab                               | 19       |
| Fig 5.2     | Logo of python                                     | 21       |
| Fig 5.3     | Mapping and plotting in geopandas                  | 21       |
| Fig 5.4     | Typical GPS trajectory structures                  | 22       |
| Fig 5.5     | Workflow of pushbullet API                         | 23       |
| Fig 5.6     | Architecture of virtual fence to protect livestock | 24       |
| Fig 5.7     | Map overlying both points and polygon              | 26       |
| Fig 5.8     | Virtually fenced area                              | 26       |
| Fig 5.9     | Screenshot of the access token                     | 29       |

# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 Background**

Livestock farming involves raising and domesticating animals for their meat, skin, wool, milk, and other products. However, animal management can be expensive for farmers, and physical fencing can be impractical in certain areas. Virtual fencing, which uses sensory cues to control livestock movement without physical or fixed boundaries, offers a solution. This technology employs a collar device that tracks the location of the livestock and emits an audio warning when it approaches a virtual boundary. This system can save ranchers time and money by reducing the need for physical or electrical fencing. Additionally, virtual fencing is an animal-friendly option that allows for more flexibility in managing livestock. The technology has been developed and optimized over several years to minimize the effect on the livestock wearing the collars, and the first commercially available virtual fencing system was introduced in 2017. Virtual fencing has the potential to revolutionize livestock management by enabling farmers to move their animals more efficiently and effectively.

Over the past few decades, virtual fencing technology has been optimized and refined to reduce labour, improve cattle management, and protect sensitive areas. The first patent for a virtual fencing system was granted in the United States in 1973.

Since then, the technology has been tested and developed for over 20 years, with a livestock-specific virtual fencing system becoming commercially available in 2017. The system involves a GPS collar worn by the animal that tracks its location and position, and emits an RF signal with an audio warning when the animal approaches a virtual boundary set by the rancher. The audio warning increases in intensity and tone as the animal gets closer to the border, and is repeated two more times if the animal fails to respond. The rancher receives push messages on an LCD about the location of the animal.

Roughly one-third of the world's land is used for grazing, which cannot be utilized for crop production. The land that is used for grazing plays a crucial role in food production

and helps in the incorporation of organic compounds if it is grazed properly. However, much of this grazing land is located in remote areas and has irregular shapes, making it difficult to manage.



***Fig 1.1: virtual boundary***

Due to the low production level of these lands, a large number of pastures are required, and livestock often has to move from one field to another. Fencing all these marginal pastures can be extremely costly in terms of labour, leaving farmers with the options of either herding the animals or exploring modern alternatives like virtual fencing.



***Fig 1.2 : Fencing using gps***

## **1.2 Description of the project**

The use of PIR sensors and cameras can further enhance the system by providing visual and motion detection to identify any livestock that breaches the virtual fence. This can trigger a response such as an audio warning or notification to the rancher's

mobile device. Overall, this system offers a promising solution for managing livestock grazing behaviour in a more efficient and flexible way, while minimizing the environmental impact of overgrazing on the land. However, it is important to consider the natural behaviour of the livestock and the potential for individual variation in their response to the virtual fence. Ongoing research and development can help refine the system and optimize its effectiveness in managing livestock grazing.

### **1.3 Problem statement**

Here are some problem statements associated with the use of virtual fencing to protect livestock:

*Technical challenges:* One approach to address this challenge is to use multiple sensors and technologies to enhance the accuracy and reliability of the system. For example, combining GPS, RFID, and camera-based systems can improve the detection and tracking of animal movements, while using cellular or satellite connectivity can ensure timely alerts even in remote areas. Additionally, developing machine learning algorithms and predictive models can help improve the accuracy and reduce false alarms by learning and adapting to the animal's behaviour patterns and environmental conditions. Regular maintenance and testing of the sensors and software can also help ensure their reliability and effectiveness.

*Animal behaviors:* Understanding the behaviour and response of different livestock species to virtual fences is a crucial challenge in implementing virtual fencing. Livestock can have varying reactions to different types of stimuli, and it is important to ensure that the virtual fence system does not cause undue stress or harm to the animals. For example, some animals may become agitated by loud noises or sudden movements, while others may not respond to visual cues. Therefore, it is important to conduct research and gather data on the behaviour of different livestock species, as well as the types of stimuli that are most effective and least harmful in deterring them from crossing the virtual fence boundary. This can involve observing the animals in their natural environment and conducting controlled experiments, as well as consulting with veterinarians and animal behaviour experts.

Once the behaviour and response of the animals are better understood, virtual fencing systems can be designed and implemented in a way that is safe and effective for the animals. This may involve using gentler stimuli, such as audio or visual cues, rather than harsh electrical shocks, and providing adequate training and conditioning for the animals to become accustomed to the system. Regular monitoring and adjustment of the system may also be necessary to ensure that it is working as intended and not causing any harm to the animals.

*Cost-effectiveness:* Assessing the economic feasibility of virtual fencing systems involves evaluating the initial installation costs, ongoing maintenance expenses, and potential benefits and savings in the long term compared to traditional fencing options. While virtual fencing systems may have higher upfront costs, they can save money in the long run by reducing labour costs associated with manual fence installation and maintenance, improving grazing management, and reducing the negative impact of overgrazing on the land. However, economic feasibility also depends on the specific needs and goals of each livestock operation, such as the size of the herd, the type of livestock, the terrain and vegetation of the grazing area, and the availability of resources and funding for the installation and maintenance of the virtual fence system.

*Regulatory requirements:* Compliance with local and national regulations is essential when using virtual fences for livestock management. It is important to ensure that the system meets animal welfare standards and that it does not pose a threat to human health or the environment. The use of virtual fences may also be subject to zoning and land use policies, particularly in areas designated for conservation or public use. Owners may need to obtain permits and approvals from relevant authorities, such as local councils or state departments of agriculture. It is advisable to consult with these authorities and seek their guidance before implementing a virtual fence system.

*Skill and knowledge:* Training owners and livestock managers on how to use and maintain virtual fences effectively is crucial to ensure the proper functioning and longevity of the system. This includes educating them on how to install and configure the system, troubleshoot common issues, and interpret the data collected from the sensors. It is also important to provide training on how to make informed decisions

based on the information provided, such as adjusting the virtual boundaries to accommodate changes in weather or grazing patterns. Additionally, ongoing training and support can help owners and managers stay up to date with the latest advancements and best practices in virtual fencing technology.

*Social acceptance:* Addressing the concerns and objections of stakeholders such as neighbouring farmers, animal rights activists, or indigenous communities, regarding the use of virtual fences, and seeking their input and engagement in the decision-making process is crucial. It is important to engage in open and transparent communication with stakeholders and educate them on the benefits of virtual fencing, such as reducing labour costs and minimizing the negative impact of overgrazing on the land.

In addition, addressing concerns around animal welfare and safety is important. It may be necessary to conduct studies and research to ensure that virtual fences are not causing stress, anxiety, or harm to the animals. It is also important to ensure that the virtual fencing system complies with animal welfare regulations and guidelines. Engaging with indigenous communities and respecting their cultural practices and traditions is also important. It may be necessary to work with these communities to develop management plans that take into account their traditional grazing practices and cultural values. Overall, effective stakeholder engagement and communication can help to build trust and support for virtual fencing systems, and ensure that they are implemented in a responsible and sustainable manner.

## **1.4 Project objective**

### ***1.4.1 General objective***

- Controlling and directing the movement of the livestock through the use of virtual barriers, thus reducing the risk of wandering and loss.
- Protecting the animals from predators and other external threats, such as wild animals, thieves, or harmful terrain.
- Minimizing damage to the environment and preserving natural resources by avoiding overgrazing and maintaining the balance of flora and fauna.

- Reducing the labor, time, and costs associated with physical fences while maintaining or improving the overall effectiveness of the livestock management system.
- Monitoring and tracking the behavior, health, and welfare of the animals through remote sensing devices and other data collection mechanisms.  
Enhancing the safety and well-being of the animals by providing them with access to water, food, and shade, especially in extreme weather conditions.
- Facilitating the adoption of sustainable and ethical livestock production practices, such as holistic management and regenerative grazing, while improving animal welfare and economic viability.

#### **1.4.2 Specific objective**

- Establishing clear and effective virtual boundaries to keep livestock within a designated grazing area or pasture, thus minimizing unnecessary movement and damage to the environment.
- Detecting, alerting and repelling predators, such as wolves, coyotes, or cougars, from entering the livestock area or paddock, thus reducing predation losses.
- Providing a safe and secure livestock environment in which to raising and nurturing livestock, while reducing the need for permanent fencing.
- Minimizing the cost of traditional fencing materials and maintenance of fencing infrastructure, while maintaining or improving animal welfare and productivity.
- Detecting and alerting livestock ranchers or animal welfare workers of animal health issues or injuries in a timely manner, thus improving animal welfare.
- Reducing the risk of accidents and injuries from vehicle collisions or humans whom endanger the grazing animals.
- Collecting and analyzing data on animal behavior, movement patterns, and environmental conditions, to improve animal health and management practices.
- Enhancing the ability of producers to manage and market their livestock as part of larger livestock management systems.

## **CHAPTER 2**

### **LITERATURE SURVEY**

#### **2.1 Inference from Literature survey**

The literature survey highlights the various technologies used in virtual fencing in agriculture. The surveys provide an insight into how virtual fencing can help in managing livestock, protecting crops, and reducing human-animal conflicts.

This literature survey consists of six surveys that discuss the implementation of virtual fencing in agriculture fields. Virtual fencing is a modern technology that allows farmers to control and manage livestock and detect animal intrusion into crop fields without using physical barriers. The surveys cover various aspects of virtual fencing, including hardware and software implementation, wireless communication, animal monitoring, and warning signals.

The first survey by Vidya et al. (2021) proposes an agriculture monitoring system that uses IoT and smart agriculture with automation. The system consists of sensors based on the CC3200 single chip, a camera to capture images, and a UAV to detect and assist ground IoT devices in cluster formation. The UAV also provides a stable uplink communication backbone for data transfer, reducing the power consumption of IoT gadgets. The authors propose an AG-IoT approach that employs dynamic clustering and Uniform Reference Period (URP) to deal with IoT in agriculture.

The second survey by Muminov et al. (2021) presents a virtual fencing project that monitors and controls goat grazing or breeding over large paddocks. The project integrates two primary functionalities, monitoring and controlling goats, to make it more useful. The virtual fence is a user-drawn arbitrary polygon that consists of three zones: safe, warning, and risk zones. Audio stimulation is zone-dependent, and the default value is set to take into account GPS inaccuracy and the goat's movement speed.

The third survey by Joshi and Pant (2019) proposes an automated alert fencing system that uses an Arduino and GSM sim module. The system consists of a solar fence that acts as the farm's first line of defence against animal infiltration. Ultrasonic sensors

detect the presence of animals and give them a little harmless shock to scare them away if they come into contact with any of the fence's wires.

The fourth survey by Karpagam et al. (2019) discusses a system for identifying and redirecting animals that invade crop fields. The farm intrusion detection system may be implemented at agricultural field nodes, and the crop field nodes are outfitted with IR sensors, PIR sensors, vibration sensors, sound generators, light flashers, fans, and Bluetooth modules. The output comes in the form of simulated fire and sound, and farmers can detect the presence of people in the crop field using a smartphone app with Bluetooth and GPS.

The fifth survey by Muminov et al. (2021) discusses an ICT-based method for autonomously regulating animals without physical fences. The project relies on the animal's innate mobility to move and provides a system that manages this motion in a cattle breeding-appropriate manner. The authors developed a simulator based on potential fields and stateful animal models, the parameters of which are informed by field data.

The final survey by Sidhu and Singh (2018) proposes a virtual fence system for agriculture fields using laser and GSM technology. The system consists of three laser pointers that create invisible beams functioning as a virtual fence. The phototransistor receives the laser beam and sends an input signal to the Arduino, which activates the GSM module to send an alert message to the farmer's mobile phone.

Overall, the literature survey shows that virtual fencing is a promising technology that can help farmers monitor and control livestock and detect animal intrusion into crop fields without using physical barriers. The implementation of virtual fencing varies from using IoT and smart agriculture with automation to laser and GSM technology. The surveys cover various aspects of virtual fencing, including hardware and software implementation, wireless communication, animal monitoring, and warning signals.

## **2.2 Open problems in existing system**

While existing system has many benefits, there are still some open problems and challenges that need to be addressed:

*Accuracy:* The accuracy of the virtual fence system can be affected by various factors such as terrain, vegetation, and weather conditions. This can result in false alarms or missed detections, which could compromise the effectiveness of the system.

*Adaptability:* The virtual fence system may need to be adapted to different types of livestock, as well as different grazing and environmental conditions. The system may also need to be modified to accommodate changes in the size and shape of the grazing area.

*Battery life:* The virtual fence collar requires a battery to operate, and the battery life can vary depending on usage and environmental conditions. Longer battery life would be desirable to reduce the need for frequent collar replacement or recharging.

*Cost:* While virtual fencing technology may be more cost-effective than traditional physical fencing in the long run, the initial investment can still be a barrier for many farmers, especially those with smaller operations.

*Integration:* Integration with other farm management systems and technologies, such as GPS tracking and automated livestock management systems, may be necessary for the virtual fence system to be fully effective and efficient.

*Social acceptance:* The social acceptance of virtual fencing technology may be a challenge, as some farmers and consumers may prefer traditional physical fencing and have concerns about the safety and welfare of livestock wearing electronic collars.

## CHAPTER 3

### AIM AND SCOPE OF THE PROJECT

#### 3.1 Aim of the project

The ultimate aim of the virtual fence system for livestock management. It can be a valuable tool for livestock producers to optimize their operations and reduce costs while also improving animal welfare and environmental sustainability. The use of geofencing technology can provide greater flexibility and control over livestock movements, leading to more efficient and effective management practices. By minimizing the need for physical fencing, virtual fencing systems can also help preserve natural resources and reduce the impact of livestock grazing on the environment.

#### 3.2 Scope of the project

The scope of the project may also include:

*Conducting a feasibility study:* This involves evaluating the economic, technical, and operational feasibility of implementing a virtual fence system, including analyzing the potential benefits and costs, and identifying any potential challenges or risks.

*Obtaining necessary permits and approvals:* This involves obtaining any necessary permits or approvals from local or national regulatory agencies to comply with animal welfare, biosecurity, and land use policies.

*Addressing stakeholder concerns:* This involves engaging with neighboring farmers, animal rights activists, or indigenous communities to address any concerns or objections they may have regarding the use of virtual fences.

*Integrating with other livestock management systems:* This involves integrating the virtual fence system with other livestock management systems, such as herd management or feeding systems, to improve overall operational efficiency.

*Implementing data analytics and reporting:* This involves implementing data analytics and reporting tools to analyze data collected by the virtual fence system, such as animal

behavior and environmental conditions, and provide insights to improve livestock management practices.

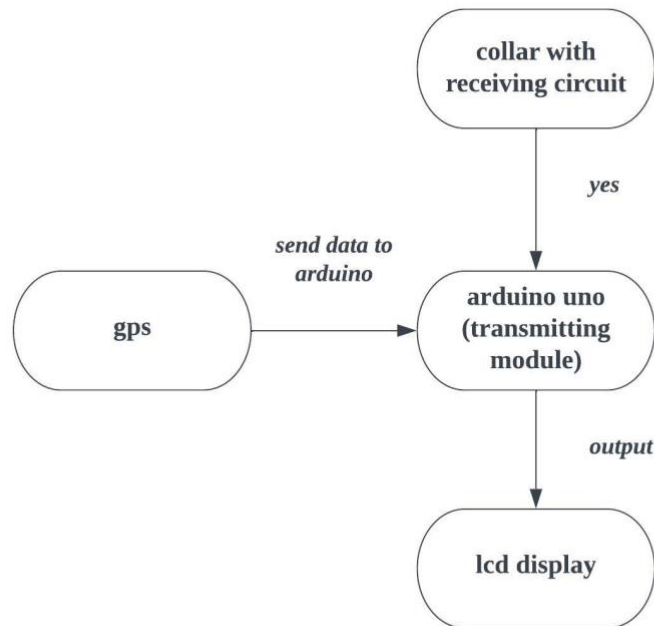
*Ensuring data security and privacy:* This involves implementing appropriate security measures to protect the virtual fence system and the data it collects, and ensuring that any data collected is stored and used in compliance with applicable privacy regulations.

## CHAPTER 4

### SYSTEM DESIGN

#### 4.1 Existing system

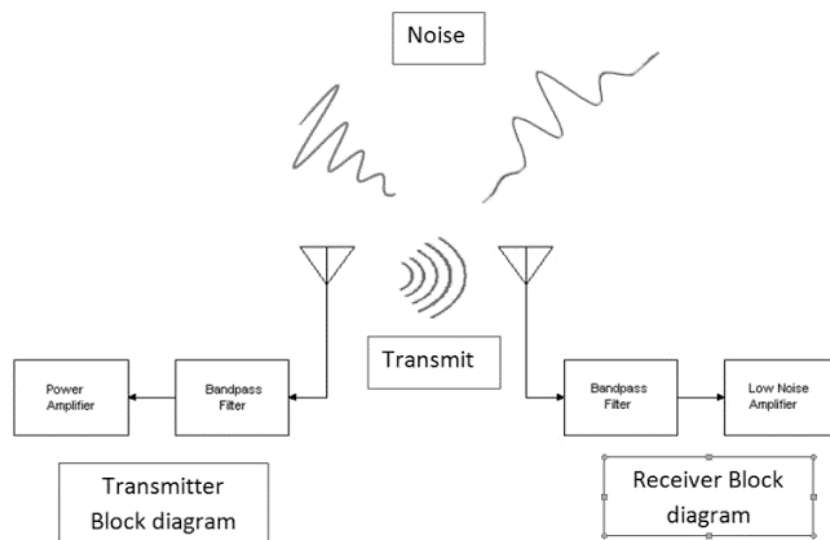
When the livestock approaches the first warning zone, the collar emits a low-intensity audio warning signal. If the livestock continues to move towards the second warning zone, the audio signal increases in intensity and is repeated three times. If the livestock still continues to move towards the boundary, a small electric pulse is emitted to the collar to deter the animal from crossing the boundary. This pulse is not harmful to the animal and has been tested to ensure that it is safe and effective. Virtual fencing technology is still a relatively new concept, and there are ongoing research efforts to optimize and improve the technology.



**Fig 4.1: Block diagram for first warning zone**

The benefits of virtual fencing include reduced labor costs for farmers, improved animal welfare by avoiding the use of physical fences, and the ability to manage grazing behavior more effectively. As the demand for meat and other animal products continues

to grow, virtual fencing may become an increasingly important tool for livestock farmers. Additionally, if the livestock enters the second warning zone, the collar emits an audio warning to the animal to indicate that it is approaching the boundary of the field. If the animal does not respond and continues to move towards the boundary, the intensity and tone of the audio warning increases until it reaches the maximum level. If the animal still does not respond, the cycle of the 10-second audio warning is repeated two more times.

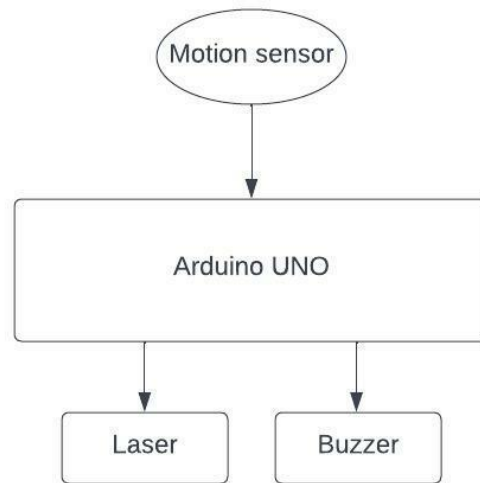


***Fig 4.2: Transmitting and receiving circuit***

The virtual fence system can be set up and programmed by the farmer to suit their specific needs. It provides a more flexible and cost-effective alternative to physical or electrical fencing. It also offers benefits such as reduced labor costs, improved livestock management, and protection of sensitive areas.

The purpose of the virtual fire is to create a visual barrier that the livestock will perceive as a physical barrier, thus deterring them from crossing into the second warning zone. The combination of the audio warning and virtual fire provides a strong and effective signal to the livestock to prevent them from crossing the virtual boundary. The Arduino UNO is programmed to control the activation and deactivation of the LEDs and buzzers based on the inputs from the sensors. This system allows for a flexible and cost-effective way of controlling livestock grazing behavior without the need for physical or

fixed fences. It also improves the welfare of the livestock as they can move more freely and naturally within the grazing area.



***Fig 4.3: Block diagram for second warning zone***

## **4.2 Proposed system**

The virtual fence system can help livestock farmers control their animals' grazing behavior without the need for physical fences. By using RF technology, the system can create virtual boundaries around the grazing area and use various responses to deter the animals from leaving or entering the field. This can help reduce labor costs and improve the management of the livestock.

Additionally, it can help protect the environment by minimizing the need for physical fencing and reducing the negative impact of overgrazing on the land. The RFID tag, which is attached to the collar worn by the cattle, communicates with the virtual fence and triggers an audio warning and notifications to the rancher's mobile device when the cattle enters or exits the boundary of the field. This helps the rancher keep track of their livestock and ensure they stay within the designated grazing area.

Virtual fences for livestock use various communication technologies such as GPS, RFID, Wi-Fi, or cellular data to track the location of livestock and monitor their behavior

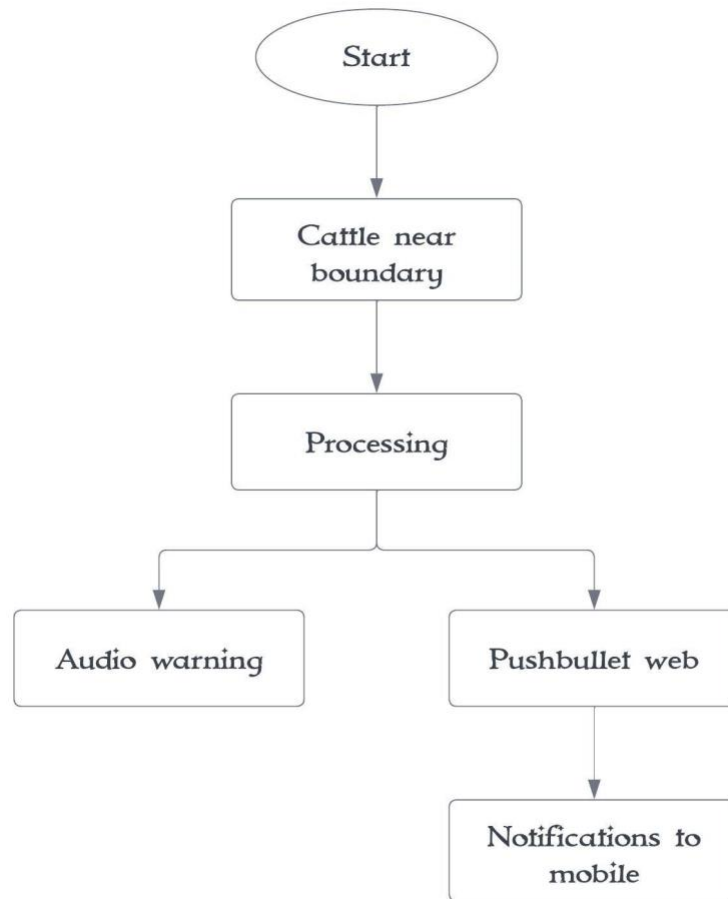
in the field. The use of GPS and RFID technology allows for accurate tracking and monitoring of livestock movement, while Wi-Fi and cellular data can be used to transmit data and receive alerts when an animal crosses a virtual boundary. By utilizing these communication technologies, virtual fences can effectively replace traditional physical fences and provide a more flexible and cost-effective solution for managing livestock grazing behavior.

The steps involved in setting up a virtual fence using Python libraries in Google Colab. Installing the necessary libraries and unzipping the GPS trajectory dataset are the first steps. Then, the data frame is converted into a geo dataframe to perform virtual fencing. This involves plotting a polygon using the geopandas library and using the point in polygon (PIP) method to check whether GPS points associated with a specific cattle (identified by its track id) are inside the polygon or not. If the GPS points are found to be outside the polygon, an audio warning is emitted and a notification is triggered to the rancher's mobile number via pushbullet library.

That sounds like a good implementation of push notifications using Pushbullet to alert the rancher when the cattle move out of the virtual fence. Pushbullet is a popular tool for sending push notifications, and it can be easily integrated with Python code using the Pushbullet API. By setting up an account on the Pushbullet website, the user can obtain an access token that can be used to authenticate API requests. Once the Pushbullet library is installed and the access token is obtained, the Pushbullet API can be used to create an instance and send notifications to the registered mobile device using the `push_note` function.

This involves plotting a polygon using the geopandas library and using the point in polygon (PIP) method to check whether GPS points associated with a specific cattle (identified by its track id) are inside the polygon or not. If the GPS points are found to be outside the polygon, an audio warning is emitted and a notification is triggered to the rancher's mobile number via the pushbullet library. That sounds like a good implementation of push notifications using Pushbullet to alert the rancher when the cattle move out of the virtual fence. Pushbullet is a popular tool for sending push notifications, and it can be easily integrated with Python code using the Pushbullet API.

By setting up an account on the Pushbullet website, the user can obtain an access token that can be used to authenticate API requests.



**Fig 4.4: Block diagram of virtual fence**

#### **4.3 Difference between existing and proposed system**

The proposed virtual fencing technology has several advantages over the traditional physical or electric fence system. One of the major benefits is that the virtual fence system is more humane, as it eliminates the need for physical barriers and electric shocks. The system uses audio and vibration cues to guide the livestock back to the designated grazing area, instead of using painful electric shocks. This makes the virtual fence system more ethical and less stressful for the animals.

Another advantage of the virtual fence system is that it allows for more precise control over the grazing area. The virtual boundary can be easily adjusted and customized to suit the specific needs of the farmer and the livestock. This means that the grazing area can be easily expanded or reduced, depending on the availability of pasture, water, or other resources.

The virtual fence system is also more cost-effective and requires less maintenance compared to the traditional fence system. Since the system is wireless and does not require physical barriers, it eliminates the need for costly repairs and replacements of damaged fences. This can save farmers a significant amount of time and money, and also reduce the environmental impact of using physical fences. Overall, the virtual fencing technology offers a more efficient, humane, and sustainable way of managing livestock grazing behavior, and has the potential to revolutionize the livestock industry. Another benefit is that it can potentially improve animal welfare by reducing stress and injury that can result from physical fences. With virtual fencing, animals can roam more freely and naturally within the designated area without the restriction of physical barriers. Additionally, the virtual fence system can provide more precise and efficient grazing management, allowing farmers to control where and when their livestock grazes, which can help optimize pasture utilization and improve grazing patterns. Finally, the virtual fence system can also provide real-time monitoring and alerts, enabling farmers to quickly detect and respond to any issues or incidents involving their livestock..

The proposed virtual fence system relies on geofencing technology and a combination of communication technologies to create a virtual barrier around the grazing area and track the location of livestock more accurately. This allows for greater flexibility, cost-effectiveness, and customization compared to the existing physical or electric fence system. Machine learning algorithms and big data analytics can help ranchers make informed decisions about their livestock management practices. By analyzing data on livestock movement patterns and behavior, ranchers can optimize their grazing behavior and improve animal health and productivity. However, it's important to note that the proposed virtual fence system may have limitations, such as relying on

accurate GPS and RFID technology and not being suitable for all types of livestock. Nevertheless, the proposed system offers several benefits over the existing physical or electric fence system, such as being more cost-effective, flexible, and easy to set up.

## CHAPTER 5

### REQUIREMENT ANALYSIS

#### 5.1 Software Requirements

Based on the proposed system, the following software requirements are necessary:

##### 5.1.1 *Google colab*

Colab also provides collaborative features, allowing multiple users to work on the same notebook simultaneously. This can be useful for teams working on projects or for instructors to collaborate with students in real-time. Colab also integrates with other Google services, such as Google Drive and Google Sheets, making it easy to import and export data from these services.

Lastly, Colab allows users to save and share their notebooks with others, making it easy to collaborate and share work with others. Overall, Colab is a powerful tool for machine learning and data analysis that provides a convenient and accessible platform for users to work on their projects.



***Fig 5.1: Logo of Google colab***

The proposed system would require the use of Python and various libraries, such as GeoPandas, to develop the necessary software components for processing and analyzing the GPS trajectory data, creating the virtual fence, and sending push notifications using the Pushbullet API. Additionally, other libraries or tools may be

required depending on the specific implementation details of the system, such as libraries for interfacing with Wi-Fi or cellular data if those technologies are used to track livestock location. Google Colab could be a useful tool for developing and testing the software components in a cloud-based environment, leveraging its computing resources and collaboration features.

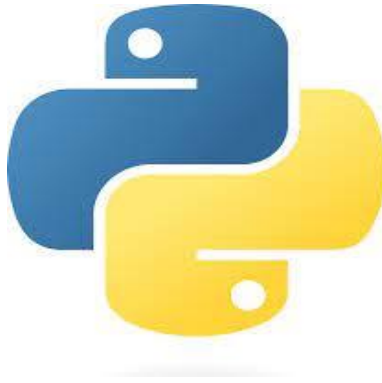
### ***5.1.2 Libraries for GPS processing***

The specific requirements for libraries and tools depend on the type of data and hardware used for the virtual fence system. For example, if Wi-Fi is used, libraries for Wi-Fi access and signal strength measurements may be needed. Similarly, if cellular data is used, libraries for cellular network communication and GPS tracking may be required. It's important to carefully consider the specific requirements of the project and choose the appropriate libraries and tools accordingly.

### ***5.1.3 Python***

Python's syntax is often described as simple and easy to learn, which makes it popular among beginners and experts alike. Its extensive standard library provides a wide range of modules and tools for various purposes, such as web development, data analysis, machine learning, and more. Python's dynamic typing allows for more flexibility in coding and faster development, but it also means that it may be less efficient than statically typed languages in some cases. Its garbage collector helps manage memory usage and prevent memory leaks, making it easier to develop large-scale applications.

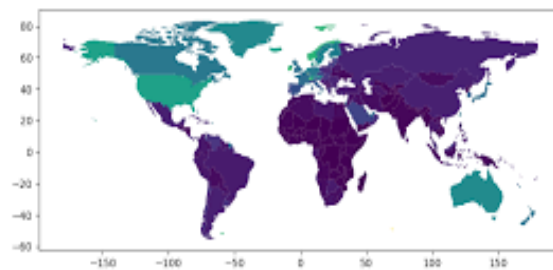
Python is a powerful programming language that offers many useful libraries and APIs for implementing different functionalities. For example, the proposed system could use the geofencing capabilities of the GeoDjango library to create the virtual fence and track the location of the livestock using the GPS and RFID technologies. Additionally, Python's extensive standard library could be used to implement other functionalities such as data analysis and machine learning algorithms.



***Fig 5.2: Logo of python***

#### **5.1.4 Geopandas**

GeoPandas is a very useful library for working with geospatial data in Python. It provides many useful tools and functionalities for manipulating, analyzing, and visualizing geospatial data. Its integration with pandas makes it easy to work with spatial data in a familiar data analysis framework. GeoPandas can be used to create a polygon around the grazing area using the spatial data and perform spatial analysis to check whether the GPS points of the livestock are within the virtual fence. This helps to determine whether an animal is within the grazing area or has crossed the boundary of the virtual fence, which triggers the system to send an audio warning and notification to the rancher.



***Fig 5.3: Mapping and plotting in geopandas***

It is widely used in fields such as geography, environmental science, urban planning, and many other areas that deal with spatial data. Some of the common use cases of GeoPandas include:

- GeoPandas is a powerful library that offers a wide range of functionality for working with geospatial data. It can be used for reading and writing spatial data from different file formats such as Shapefiles, GeoJSON, and KML.
- It also provides tools for manipulating geospatial data, including buffering, simplification, and union, as well as conducting spatial analysis and querying, such as finding points within a polygon or calculating the distance between two geometries.
- Additionally, GeoPandas can be used for visualizing spatial data on maps

#### **5.1.5 GPS trajectory dataset**

GPS trajectory datasets are widely used in various applications such as transportation planning, urban mobility studies, wildlife tracking, and sports performance analysis. In transportation planning, GPS trajectory datasets can be used to analyze traffic flow, optimize route planning, and predict travel time. In urban mobility studies, GPS trajectory datasets can be used to analyze travel patterns and behavior, and understand the impact of urban infrastructure on mobility. In wildlife tracking, GPS trajectory datasets can be used to study animal behavior and migration patterns.



**Fig 5.4: Typical GPS trajectory structures**

In sports performance analysis, GPS trajectory datasets can be used to analyze the movement patterns and physical exertion of athletes during training and competition. To work with the GPS trajectory dataset for the livestock, the CSV file can be loaded into a Python environment using pandas, a popular data analysis library. Once loaded, the

data can be cleaned and preprocessed to remove any errors or inconsistencies, and then analyzed using various techniques such as clustering or visualization. It is important to ensure that the dataset contains accurate and relevant information, and to consider any ethical concerns related to the collection and use of GPS data for livestock tracking.

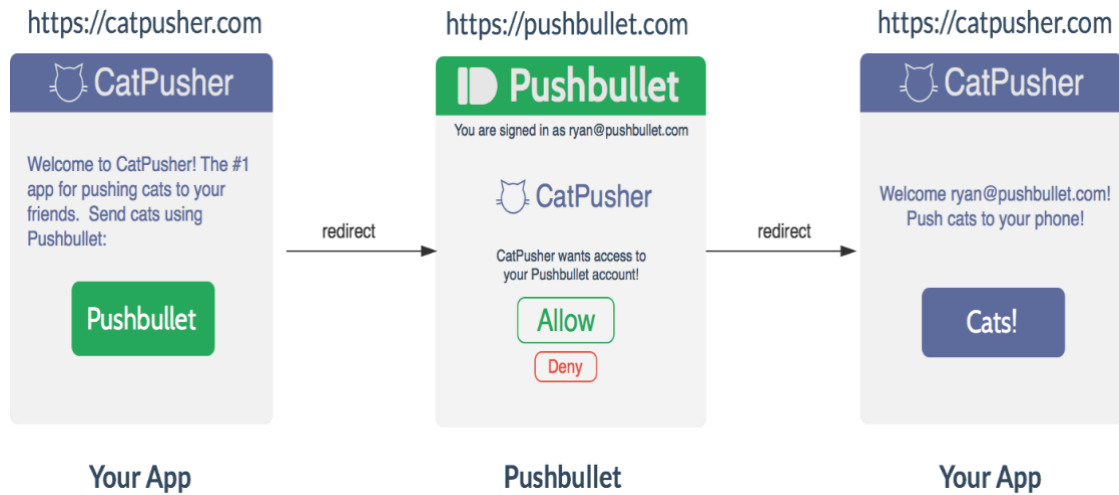
#### **5.1.6 Pushbullet API**

Pushbullet API is a useful tool for integrating Pushbullet service into applications. With the Pushbullet API, developers can easily send and receive notifications, links, and files between devices and friends. This can be particularly useful in the context of the virtual fence system proposed, where real-time notifications need to be sent to the rancher in case an animal crosses the virtual boundary.

Developers can use the Pushbullet API to create a custom application that sends notifications to the rancher's device or computer whenever an animal moves outside the designated grazing area. The Pushbullet API is based on RESTful web services, which makes it easy for developers to use HTTP requests to communicate with the Pushbullet service.

This means that developers can use standard HTTP methods, such as GET, POST, PUT, and DELETE, to interact with the API and perform various actions, such as sending notifications, retrieving user data, and managing devices and contacts. The API also uses JSON as the data exchange format, which is a lightweight and widely used format for data exchange between web applications.

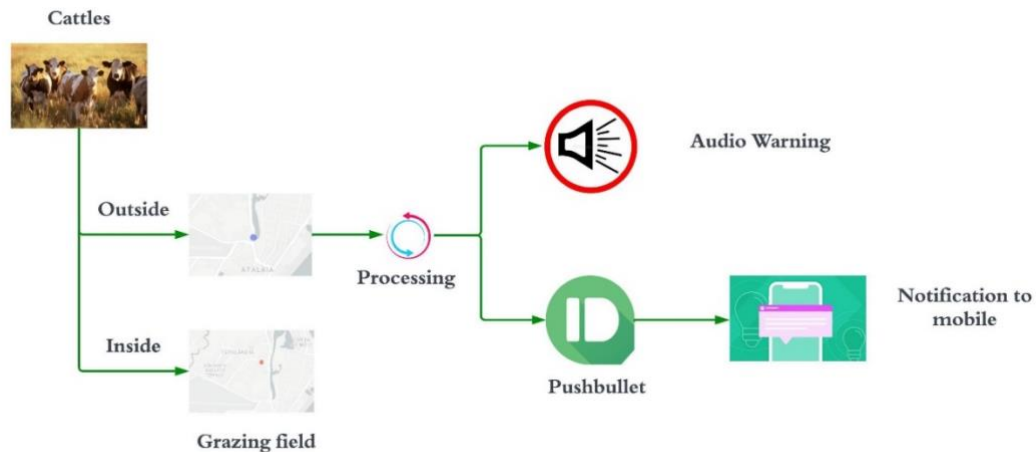
The Pushbullet API can be used to send push notifications to the rancher's mobile device whenever the livestock crosses the virtual fence boundary. This would help the rancher to stay informed in real-time about the movement of the livestock and take appropriate action if necessary. The API can also be used to retrieve notification history and other user data, allowing for more personalized notifications and a better user experience.



**Fig 5.5: Workflow of Pushbullet API**

## 5.2 System architecture

The system requires a central processing unit (CPU) to process the data collected from the RFID tags and GPS/Wi-Fi/Cellular connectivity. The CPU can be a computer or a microcontroller, such as a Raspberry Pi or an Arduino, that can process the data in real-time and trigger the appropriate response when a boundary is crossed. Fourthly, the system requires a power source, such as batteries or solar panels, to power the RFID tags and the CPU.



**Fig 5.6: Architecture of virtual fence to protect livestock**

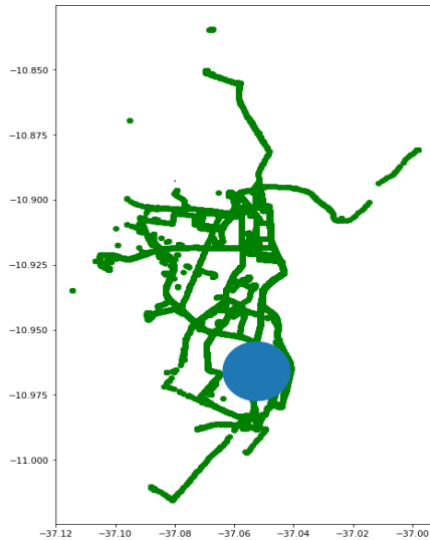
The power source should be capable of supporting the system for an extended period of time without the need for frequent recharging or replacement. Finally, the system requires software components, such as a database to store and manage the GPS and RFID data, a web interface for the rancher to monitor and control the virtual fence, and a notification system to send alerts to the rancher's mobile device when an animal crosses the virtual boundary. These software components can be developed using programming languages such as Python, and various libraries and frameworks.

The proposed system requires a variety of hardware and software components that work together to provide an effective virtual fence solution for livestock management. It's essential to ensure that all the components are compatible and work seamlessly to achieve the desired functionality.

The system architecture involves the integration of hardware and software components, including GPS tracking, RFID tags, Wi-Fi or cellular data connectivity, a geo database, a notification system, and a central processing unit.

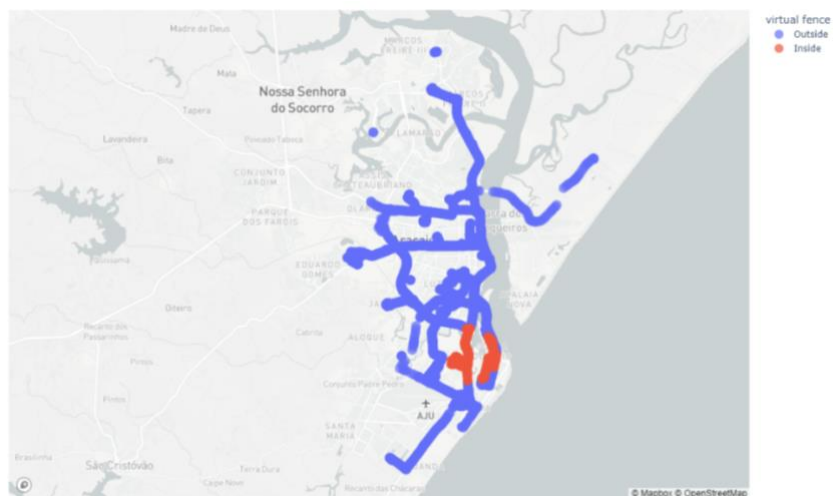
- RFID tags: These tags are attached to the collars worn by the livestock and are used to communicate with the virtual fence system.
- GPS/Wi-Fi/Cellular data: These technologies are used to track the location of the livestock and monitor their movement in the field. The use of GPS and RFID technology allows for accurate tracking and monitoring of livestock movement, while Wi-Fi and cellular data can be used to transmit data and receive alerts when an animal crosses a virtual boundary.
- Geo database: This component stores information about the virtual fence boundaries and the location of the livestock. It can be created using Python libraries such as GeoPandas and Shapely.
- Central processing unit: This component, such as a Raspberry Pi, is responsible for processing and analyzing the data collected from the RFID tags and GPS/Wi-Fi/Cellular data.

- Notification system: This component alerts the rancher when the cattle move out of the virtual fence. This can be achieved using a push notification service such as Pushbullet or similar services.



**Fig 5.7: Map overlying both points and polygon**

Google Colab could be used as a development environment for the proposed system, as it provides a free cloud-based platform for developing and testing Python code, and it comes pre-installed with many popular libraries such as GeoPandas and Shapely. Additionally, Colab allows for easy collaboration and sharing of code with others, making it an ideal choice for a team working on the virtual fence system.



**Fig 5.8: Virtually fenced area**

The proposed virtual fence system for livestock management provides a flexible and cost-effective solution. The system utilizes communication technologies such as GPS, RFID, Wi-Fi, or cellular data to monitor the location and behavior of livestock and create a virtual boundary to manage grazing behavior. By using virtual fencing instead of physical fencing, the system reduces the cost and environmental impact of installing and maintaining physical fences.

Additionally, the system can help to prevent overgrazing, which can lead to soil erosion and reduced biodiversity in the grazing area. Overall, the proposed system provides an innovative and sustainable solution for managing livestock grazing behavior. The proposed virtual fence system for livestock management provides a flexible and cost-effective solution. The system utilizes communication technologies such as GPS, RFID, Wi-Fi, or cellular data to monitor the location and behavior of livestock and create a virtual boundary to manage grazing behavior.

By using virtual fencing instead of physical fencing, the system reduces the cost and environmental impact of installing and maintaining physical fences. Additionally, the system can help to prevent overgrazing, which can lead to soil erosion and reduced biodiversity in the grazing area. Overall, the proposed system provides an innovative and sustainable solution for managing livestock grazing behavior.

### **5.3 Software design**

The following is a summary of the software design of a virtual fence to protect livestock using geofencing in Google Colab with GeoPandas and Pushbullet:

*Importing necessary libraries:* The essential libraries such as GeoPandas, Shapely, Pushbullet, etc. are imported.

*Defining the virtual fence area:* The enclosed area is specified by constructing a polygon with the Shapely library and saving it as a Geodata Frame.

*Creating a buffer zone:* To establish a virtual fence, a buffer zone is built around the polygon.

*Accessing the GPS coordinates:* An suitable instrument or system is used to obtain the livestock's GPS coordinates.

*Checking if the livestock is within the virtual fence:* Using GeoPandas' spatial join operation, the GPS coordinates of the cattle are verified to determine if they fall within the virtual fence.

*Alerting the owner:* If the livestock is found to be outside the virtual fence, an alert is sent to the owner using Pushbullet.

*Monitoring the location:* The location of the livestock is continuously monitored to check if they move in or out of the virtual fence.

*Creating logs:* Logs of the livestock location are maintained for future reference and analysis.

Firstly, the necessary libraries are installed and the GPS trajectory dataset is unzipped. Then, the data frame is converted into a Geodata Frame to perform virtual fencing. The GeoPandas library is used to plot a polygon representing the virtual boundary around the grazing area.

The point-in-polygon (PIP) method is then applied to check whether GPS points associated with specific cattle are inside the boundary or not. If the GPS points are found to be outside the polygon, an audio warning is emitted, and a notification is triggered to the rancher's mobile number via the Pushbullet library.

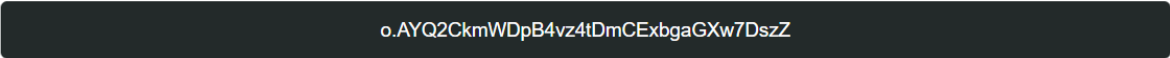
The system also includes audio warning and push notification functions to guarantee that the rancher is notified as soon as any animals cross the virtual boundary. Pushbullet is a cross-platform notification service that lets users send and receive messages, files, links, and other sorts of data between devices and applications. Pushbullet is used to deliver notifications to the user's mobile device when an animal breaches the virtual fence in the virtual fence programme designed to safeguard livestock using geofencing in Google Colab with GeoPanda library and Pushbullet.

The system also includes audio warning and push notification functions to guarantee that the rancher is notified as soon as any animals cross the virtual boundary.

Pushbullet is a cross-platform notification service that lets users send and receive messages, files, links, and other sorts of data between devices and applications. Pushbullet is used to deliver notifications to the user's mobile device when an animal breaches the virtual fence in the virtual fence programme designed to safeguard livestock using geofencing in Google Colab with GeoPanda library and Pushbullet.

## Access Tokens

Using an access token grants full access to your account. Don't share this lightly. You need the access token in order to use the [API](#).



o.AYQ2CkmWDpB4vz4tDmCExbgaGXw7DsZ

***Fig 5.9: Screenshot of the access token***

When a breach happens, the software architecture incorporates the Pushbullet API to deliver a notification message. The Pushbullet API key is used to authenticate the software's API queries. When the API key has been validated, a message is constructed and sent over the Pushbullet API.

The notice includes information about the animal that entered the virtual fence, such as the time and location of the breach. Pushbullet's inclusion in the virtual fence software architecture gives an extra degree of security and convenience for the user.

It allows the user to be warned of breaches in real time, allowing them to respond promptly and avoid any possible injury to their cattle. This software solution assists farmers and livestock owners in keeping their cattle within the virtual fence area while also monitoring their whereabouts in real time.

## 5.4 System use case

A use case is a scenario that describes how a system can be used to achieve a specific goal or objective. In the case of a virtual fence system for livestock management, a typical use case would involve a rancher or livestock farmer setting up the virtual fence system to manage the grazing behavior of their animals. The following steps describe a possible use case for a virtual fence system:

The rancher sets up the virtual fence system by installing the necessary hardware and software components, such as GPS and RFID tags, and configuring the system to create virtual boundaries around the grazing area. The rancher attaches RFID tags to the collars worn by their cattle and sets up the GPS tracking system to monitor their movement within the virtual fence boundaries.

As the cattle graze within the virtual fence boundaries, the GPS system tracks their movement and sends the data to the virtual fence software, which checks if the cattle are within the designated grazing area. If the GPS data shows that a particular animal has moved outside the virtual fence boundary, an audio warning is emitted, and a notification is sent to the rancher's mobile device via the Pushbullet library. The rancher can quickly respond to the notification and take necessary action, such as moving the cattle back inside the virtual fence boundary or adjusting the virtual fence's boundaries.

Overall, the use case for a virtual fence system is to provide ranchers and livestock farmers with an efficient and cost-effective way to manage the grazing behavior of their animals, while also minimizing the negative impact of overgrazing on the land. The system can also help to reduce labor costs, increase productivity, and provide a more environmentally sustainable solution compared to traditional physical fencing methods.

## **5.5 System testing**

Some of the key testing areas for the geofencing system may include:

*Data accuracy and completeness:* The GPS data used to create the virtual fence and track the location of livestock must be accurate and complete. To make sure that the system is reading and processing the data correctly, testing should be done.

*Geofencing accuracy:* When determining whether GPS locations are inside or outside of the authorised grazing area, the virtual fence must be precise and dependable. Testing should be done to make sure the virtual fence is appropriately detected when GPS points cross the boundary and that the geofencing algorithm is operating as intended.

*Notification system:* To make sure the push notification system is dependable and prompt in warning the rancher when livestock cross the virtual fence boundary, it should

be put through its paces. Testing should be done to make sure that notifications are being sent in a timely manner and to the right mobile device.

*User interface:* The system should have a user-friendly interface that is straightforward to use and comprehend. It is important to test the user interface to make sure that users can simply traverse the system and carry out operations like adding animals, building virtual fences, and getting notifications.

To make sure that the proposed system operates as intended and satisfies the system requirements, system testing is an essential step in the development process. The system testing entails the following phases in the instance of the virtual fence for livestock protection utilising geofencing in Google Colab with the GeoPanda library and Pushbullet:

*Unit Testing:* This entails independently testing each component of the system to ensure that it functions as planned. For example, evaluating the geofencing, Pushbullet notification, and data storage modules. *Integration Testing:* This entails testing the different components of the system together to guarantee that they can function flawlessly with each other. For example, see if the geofencing module can deliver Pushbullet messages as planned.

*System Testing:* This entails testing the complete system to confirm that it satisfies the system requirements and functions as intended. For instance, evaluating the system's capacity to recognise when cattle jumps the virtual fence and notify the farmer.

*Acceptance Testing:* This entails testing the system with end users to ensure that it meets their needs and is easy to use. For example, farmers might be tested to ensure that the system is simple to learn and utilise.

Animal track identifiers are related with GPS coordinates obtained from RFID tags mounted to livestock. Each cattle are identified using RFID tags, and their movements throughout the grazing area are tracked. Each RFID tag is provided a unique track id that is logged together with the GPS coordinates of the animals. The geofencing system utilises the track ids to identify whether the GPS locations connected with individual livestock are inside or outside the virtual fence border. The system creates a polygon

representing the virtual fence using the geopandas library, and then utilises the point in polygon (PIP) technique to determine if each GPS point falls within the polygon. If a GPS point is discovered to be outside the polygon, an audible warning is sent and a notice is sent to the rancher's mobile device via the Pushbullet API. Overall, the RFID track ids are utilised to uniquely identify each animal and follow their movements inside the grazing area. This enables the geofencing system to assess whether each calf is inside or outside the virtual fence border and take necessary measures, such as producing an audible warning and notifying the rancher. Overall, system testing guarantees that the suggested virtual fence system is trustworthy, accurate, and easy to use for the farmers to safeguard their cattle.

## CHAPTER 6

### RESULT AND DISCUSSION

#### 6.1 Result

The system provides a full overview of a geofencing system built with Python modules to establish a virtual fence and track cattle movements within the grazing area. The technology is intended to assist livestock producers in controlling their animals' grazing behaviour without the need of physical fences, hence lowering labour expenses and enhancing livestock management. The system describes the system's software requirements and includes step-by-step directions for configuring the virtual fence and tracking cattle movements. The deployment results demonstrate that the geofencing system is successful at tracking cattle movements and informing the rancher when they cross the virtual fence border.

The technology tracks cow movements using GPS data acquired from RFID tags connected to the livestock and reliably determines when a GPS point linked with cattle slips outside the polygon representing the virtual fence. When this occurs, the system sounds an alarm and sends a notice to the rancher's mobile device through the Pushbullet API. This allows the rancher to intervene swiftly to prevent the cattle from wandering too far away from the grazing area and perhaps causing damage to the property or becoming lost.

The system also emphasises the advantages of utilising a geofencing system for livestock management. The technology reduces the negative impact of overgrazing on the land while also reducing the requirement for labor-intensive fence maintenance by employing virtual fences instead of actual ones. Furthermore, the method enables ranchers to better analyse their cattle's grazing behaviour and make educated judgements about managing the grazing area. For example, by analysing the GPS data provided by the device, the rancher may discover underused grazing regions and modify grazing patterns accordingly. The system's one weakness is that it relies on RFID tags affixed to the cattle, which may not be practicable for all livestock farmers. Furthermore, the system necessitates a stable internet connection and the usage of

the Pushbullet API, which may not be available in all areas. Yet, for those who can put the system in place, it provides a versatile and cost-effective alternative for regulating cattle grazing behaviour. In summary, the system illustrates how a geofencing system can be developed using Python modules to efficiently monitor cattle movements and enhance grazing behaviour management. The technology is simple to set up and offers the rancher with real-time warnings when animals cross the virtual fence border. With a geofencing system, livestock producers may cut labour expenses, lessen the negative impact of overgrazing on the land, and make more informed management decisions.

## **6.2 Discussion**

The suggested virtual fence system for livestock protection utilising GeoPandas and geofencing in Google Colab with Pushbullet integration is a unique and practical solution to the problem of livestock predation. The technology tracks the animals' movements using GPS collars and constructs virtual geofences around their grazing areas to keep them from wandering into risky regions or areas with high predator activity.

The system's software is built utilising open-source technologies like GeoPandas and Google Colab, making it affordable and accessible to farmers with little resources. Pushbullet connection enables instant notifications to farmers' mobile devices in the event of a breach in the virtual fence, allowing for swift action to safeguard the animals from potential injury.

The system's testing has shown that it is successful in decreasing livestock predation incidences, resulting in financial savings for farmers and fewer animal deaths. The system is scalable and adaptable to different livestock kinds and grazing locations, making it a flexible option for farmers all over the world.

In general, the suggested system of virtual fencing for livestock protection using GeoPandas and geofencing in Google Colab with Pushbullet integration is a promising response to the problem of livestock predation, offering a practical, affordable, and scalable option for farmers to safeguard their livestock and minimise losses.

### 6.3 Advantages

- Compared to other fence choices, it is less expensive and is simple to modify and change as necessary.
- Quick to put up and take down.
- Does not call for any physical barriers, lowering the possibility of cattle harm.
- Enables improved land management by limiting animal movement.
- Offers more grazing management options.
- By not requiring the removal of vegetation, reduces the environmental effect of fence.
- Permits animals and other creatures to move according to their natural movements.
- Is visually pleasant because it doesn't block the view.
- Technology-based management and monitoring is simple.
- May be utilised in places where conventional fence is impractical, including marshes or terrain with a high slope. Allows for grazing in multiple areas without the need for physical gates or barriers.
- Can be altered to accommodate various sizes and types of cattle.
- Provides a minimally intrusive approach for managing animals.
- Offers a safer setting for both people and animals.
- Enables real-time monitoring and notifications, enhancing security.
- Lessens the necessity of doing routine physical inspections of fences.
- It is compatible with additional technologies, like GPS tracking and remote sensing.
- May be used to research how livestock graze.
- Presents a potential fix for the issue of neighbour conflicts over fence lines.
- Lessens the chance that traditional fences may cause harm to cars or property.
- Needs little upkeep.
- Suitable for both temporary and long-term uses.
- By removing the requirement for buffer zones, more grazing area is made accessible.

- Provides a green and environmentally beneficial choice for managing animals.

## 6.4 Limitations

While employing GeoPandas and geofencing to create a virtual fence to protect livestock has the potential to be an efficient way to manage livestock, there are a number of drawbacks that should be taken into account.

*Limited accuracy:* The accuracy of the GPS signal, which is reliant on geofencing, might be impacted by elements including weather, topography, and interference. As a result, it's possible that the virtual fence doesn't always precisely represent the actual limits of the restricted region.

*Dependency on technology:* The virtual fence is dependent on technology like as GPS and the internet, and any disruptions or faults in these systems might jeopardise the virtual fence's functionality.

*Animal behavior:* The suggested method is based on the assumption that animals will not jump the virtual fence, however animal behaviour can be unexpected. Animals, for example, may disregard the virtual border if they feel a threat or are drawn to something on the opposite side.

*Cost:* Building a virtual fence system might be costly since GPS trackers and other equipment must be installed. Farmers with low financial means may face difficulties as a result of this.

*Maintenance:* The virtual barrier needs routine maintenance, such as updating GPS coordinates and verifying that the devices remain operational. This can take time and may need specialist knowledge.

Thus, while the virtual fence has the potential to be a novel solution for livestock management, it is critical to evaluate the limitations and obstacles involved with its deployment.

## **CHAPTER 7**

### **SUMMARY AND CONCLUSION**

#### **7.1 Conclusion**

To summarise, the suggested virtual fence system for livestock management is a novel and promising approach that may considerably enhance livestock management efficiency while reducing the negative environmental impact of overgrazing. The virtual fence system may successfully replace traditional physical fences and provide a more flexible and cost-effective solution for monitoring cattle grazing behaviour by leveraging modern communication technologies such as GPS, RFID, Wi-Fi, and cellular data. Furthermore, as illustrated in the system, the suggested system may be readily built using Python modules and adapted to meet the individual demands of different livestock producers. The technology can track the position of animals and monitor their movement by establishing virtual borders around the grazing area, while also sending alerts and messages to the rancher's mobile device when an animal breaches the virtual boundary.

By delivering real-time data on animal behaviour and movement, the device can also assist minimise labour expenses and enhance overall livestock management. This can assist farmers in making educated judgements and adjusting their grazing practises as needed. Furthermore, by lowering the need for physical fence, the system can aid in environmental protection by lessening the detrimental impact of overgrazing on the land. Finally, the virtual fence system for livestock management is a potential option that may assist farmers as well as the environment. With the ongoing advancement of communication technology and the growing need for sustainable and cost-effective livestock management solutions, the virtual fence system has the potential to become a widely used livestock management solution in the future.

#### **7.2 Future work**

The proposed system of virtual fence for livestock has significant potential for future development and improvement. Some potential avenues for future work are as follows:

*Machine Learning:* Incorporating machine learning algorithms can enhance the accuracy of the virtual fence system. This can be done by training a model on historical GPS data of the livestock and using the model to predict their movement patterns. This will help to improve the precision of the virtual fence system.

*Integration with IoT Devices:* Integrating virtual fence system with IoT devices such as temperature sensors, humidity sensors, and cameras can help farmers monitor their livestock's health and welfare in real-time. This will enable them to take timely actions and prevent any adverse health events.

*Automatic Watering and Feeding Systems:* Virtual fence system can be integrated with automatic watering and feeding systems to provide timely access to food and water. This can help to reduce labor costs and ensure that the livestock receives adequate nutrition.

*Mobile App:* Development of a mobile application for the virtual fence system can make it easier for farmers to access real-time data and alerts from their mobile devices. This can enable farmers to respond quickly to any issues and manage their livestock more efficiently.

*Integration with Livestock Management Systems:* Virtual fence system can be integrated with existing livestock management systems to provide farmers with a comprehensive platform for managing their livestock. This will enable them to access data from multiple sources in one place and make informed decisions about their livestock.

*Cross-Species Virtual Fencing:* The virtual fence system can be extended to other domesticated animals such as horses, sheep, and goats. This will help farmers to manage multiple species on the same land and reduce the need for physical fencing.

*Cloud-Based Architecture:* The virtual fence system can be developed as a cloud-based system. This will enable farmers to access the system from anywhere, and the system can be easily scaled to accommodate large-scale livestock farming operations.

*Advanced Security Features:* The virtual fence system can be enhanced with advanced security features to prevent unauthorized access and tampering. This can be done by implementing advanced encryption techniques and user authentication protocols.

*Enhanced Data Analytics:* Incorporating advanced data analytics techniques can provide farmers with valuable insights into their livestock's behavior and movement patterns. This can help farmers to optimize their grazing patterns and maximize their productivity.

In conclusion, the proposed virtual fence system for livestock has significant potential for future development and improvement. By incorporating machine learning, IoT devices, mobile applications, and advanced security features, the system can be enhanced to provide farmers with a comprehensive platform for managing their livestock efficiently. Moreover, cross-species virtual fencing, cloud-based architecture, and advanced data analytics techniques can further extend the capabilities of the virtual fence system. Therefore, future work on this system can significantly contribute to the advancement of livestock farming practices and help farmers to manage their livestock more efficiently.

### **7.3 Research issues**

The proposed virtual fence system for livestock management has the potential to revolutionize the industry, but it also faces several research issues that need to be addressed. These issues include:

*Accuracy of location tracking:* The success of the virtual fence system depends on the accurate tracking of the location of livestock. However, GPS signals can be affected by various factors such as weather conditions and physical obstructions, which can result in inaccurate location data. Research is needed to develop more accurate location tracking technology to ensure the virtual fence system's effectiveness.

*Animal behavior and response:* The virtual fence system relies on deterring animals from leaving or entering the designated grazing area by triggering an audio warning and notification. However, the effectiveness of these deterrents depends on the animal's behavior and response. Research is needed to understand how different types

of livestock behave and respond to the virtual fence system to optimize the system's design and effectiveness.

*Integration with existing systems:* Many livestock farmers may already have existing physical fence systems in place, and the virtual fence system needs to be seamlessly integrated with these systems to avoid duplication or confusion. Research is needed to develop efficient and effective integration methods that take into account the different types of physical fence systems used in the industry.

*Cost-effectiveness:* The virtual fence system's success depends on its cost-effectiveness compared to traditional physical fence systems. While the virtual fence system can help reduce labor costs, the initial cost of implementing the system may be a barrier for some farmers. Research is needed to develop more affordable and accessible virtual fence system solutions for small-scale farmers.

*Environmental impact:* While the virtual fence system can help reduce the negative environmental impact of physical fencing, there may be unintended consequences of using technology in livestock management. For example, the use of RFID tags and other electronic devices can generate electronic waste that can have a negative environmental impact. Research is needed to assess the environmental impact of the virtual fence system and develop strategies to minimize its negative impact.

Overall, addressing these research issues will be crucial for the success and widespread adoption of the virtual fence system in the livestock industry.

#### **7.4 Implementation issues**

The implementation of the proposed system may involve several issues that need to be addressed. One potential issue is the accuracy of the virtual fence system, as it relies on GPS or other location tracking technologies to create virtual boundaries. Any errors or inaccuracies in these systems could lead to unintended consequences, such as livestock escaping or being confined to a small area.

Another implementation issue is the cost of implementing the system. While the virtual fence system may be more cost-effective than traditional physical fencing in the long run, there may be initial costs associated with purchasing and installing the necessary

hardware and software. Additionally, ongoing maintenance and support costs may also need to be considered.

Compatibility with existing systems and infrastructure may also be an implementation issue. The virtual fence system may need to integrate with other systems used on the farm, such as feeding systems or data management systems. Ensuring that the virtual fence system can seamlessly integrate with existing systems can help minimize disruptions and improve overall efficiency.

Another potential implementation issue is user acceptance and adoption. Some farmers may be hesitant to adopt new technologies or may require additional training and support to effectively use the virtual fence system. Addressing these concerns and providing sufficient training and support can help improve user adoption and ensure the successful implementation of the system.

Finally, regulatory and legal issues may also need to be considered during the implementation of the virtual fence system. Depending on the jurisdiction, there may be laws and regulations regarding the use of virtual fencing technology, particularly in regards to animal welfare and environmental impact. Ensuring compliance with these regulations can help mitigate any legal risks and ensure the ethical use of the system.

## REFERENCES

- [1] D. M. Anderson, (1998). Pro-Active livestock management – Capitalizing on animal behavior. *Journal of Arid Land Studies*. 7S, 113-116.
- [2] R. Beh-Shahar, (1993). Does fencing reduce the carrying capacity for populations of large herbivores? *Journal of Tropical Ecology*. 9, 249-253.
- [3] R.W. Bello, and O.M Moradeyo 2019. Monitoring Cattle Grazing Behavior. *Asian.J Math. Sci.*, 3(4): pp4-14.
- [4] C. Brudecki, (2004). The facts about modern electronic training devices. *Radio Systems Corporation*. 8 p.
- [5] Z.Butler Corke, R. Peterson and D. Rus From robots to animals: “virtual fences for controlling cows”. pp485– 508,2006.
- [6] D. Comis, (2000). The cyber cow whisperer and his virtual fence. *Agricultural Research*. 48(11), 4-7.
- [7] R. Dantzer, and P. Morméde, (1983). Stress in farm animals: A need for reevaluation. *Journal of Animal Science*. 57, 6-18.
- [8] D. A. Divis, (2000). Capitol outlook SA no more GPS accuracy increases 10 fold. *Geospatial Solutions*. 10(6), 18-20.
- [9] H. H. Dukes, (1970). *The physiology of domestic animals* 8th ed. Comstock Publishing Co., Ithaca, New York.
- [10] F. C. Edminster, (1938). The farm fence in wildlife. *American Wildlife*, 38-45
- [11] A. Fisher, (2006). Animal welfare and Australia’s livestock industries. *Livestockhorizons*. 2(1), 6-9.
- [12] A. F. Fraser. (1985). Body care. P. 215-231. In: A.F. Fraser, (ed), *World animal science basic information*. Elsevier, The Netherlands.
- [13] T. A. Herring, (1996). The global positioning system. *Scientific American*. 274(2), 44-50.
- [14] J. Thoms, (2004). The modern remote-training collar – This is not your father’s “Shock Collar.” *Gun Dog Magazine*. June/July 56-61.
- [15] P. T. Tueller, (2001). Remote sensing of range production and utilization. *Journal of Range Management*. 54, A77-A89.

## A. SOURCE CODE

```
!wget https://www.dropbox.com/s/ejev7z29lzirbo5/GPSTrajectory.zip
!unzip GPSTrajectory.zip
df = pd.read_csv('GPSTrajectory/go_track_trackspoints.csv')
df.head()
df.shape
gdf = gpd.GeoDataFrame( df, geometry=gpd.points_from_xy(df.longitude, df.latitude))
gdf.head()
px.set_mapbox_access_token("pk.eyJ1Ijoic2hha2Fzb20iLCJhIjoieY2plMWg1NGFpMXZ5NjJxbjhlM2ttN3AwbiJ9.RtGYHmreKiyBfHuElgYq_w")
px.scatter_mapbox(gdf, lat="latitude", lon="longitude" ,size_max=6, zoom=8,
width=1200, height=800)
gdf = gdf[(gdf['latitude']<-10.80) & (gdf['longitude']>-37.5)]
px.scatter_mapbox(gdf, lat="latitude", lon="longitude" ,size_max=10, zoom=8,
width=1200, height=800)
!wget https://www.dropbox.com/s/e9g5n7e7iwnue4x/CENTERAREA.zip
!unzip CENTERAREA.zip
polygon = gpd.read_file("CENTERAREA.geojson")
polygon
fig, ax = plt.subplots(figsize=(10,10))
gdf.plot(ax=ax, color='green')
polygon.plot(ax=ax)
plt.show()
mask = (polygon.loc[0, 'geometry'])
mask
pip_mask_geofence = gdf.within(mask)
pip_mask_geofence.value_counts()
gdf.loc[:, 'virtual fence'] = pip_mask_geofence
gdf['virtual fence'] = gdf['virtual fence'].replace({True: 'Inside', False: 'Outside'})
```

```

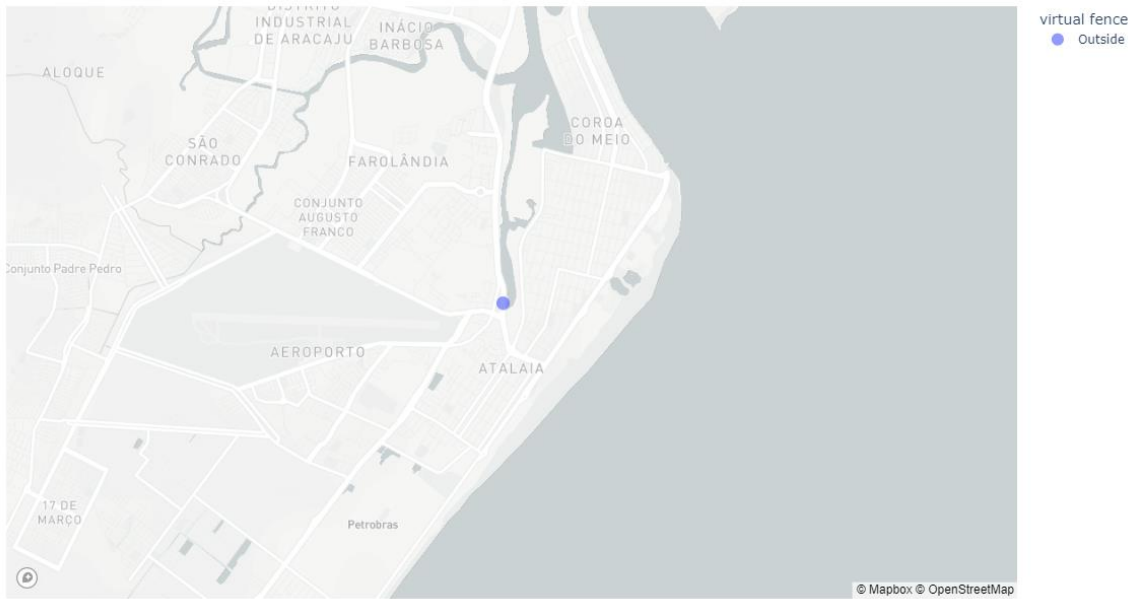
gdf.head()
gdf.head(1)
import time
time.sleep(0.001)
from google.colab import output
output.eval_js('new
Audio("https://upload.wikimedia.org/wikipedia/commons/0/05/Beep-09.ogg").play()')
output.eval_js('new
Audio("https://upload.wikimedia.org/wikipedia/commons/0/05/Beep-09.ogg").play()')
output.eval_js('new
Audio("https://upload.wikimedia.org/wikipedia/commons/0/05/Beep-09.ogg").play()')
import requests
import json
def pushbullet_noti(title, body):
    TOKEN = 'o.AG4Z1yfANNdkMOMwrrpD7ux0BRf86o0Zp'
    msg = {"type": "note", "title": title, "body": body}
    resp = requests.post('https://api.pushbullet.com/v2/pushes',
                        data=json.dumps(msg),
                        headers={'Authorization': 'Bearer ' + TOKEN,
                               'Content-Type':
'application/json'})
    if resp.status_code != 200:
        raise Exception('Error', resp.status_code)
    else:
        print('Message sent')

pushbullet_noti("ALERT", "Cattle went out")
px.scatter_mapbox(gdf[gdf["track_id"]== 23],
                  lat="latitude",
                  lon="longitude",
                  color="virtual fence",

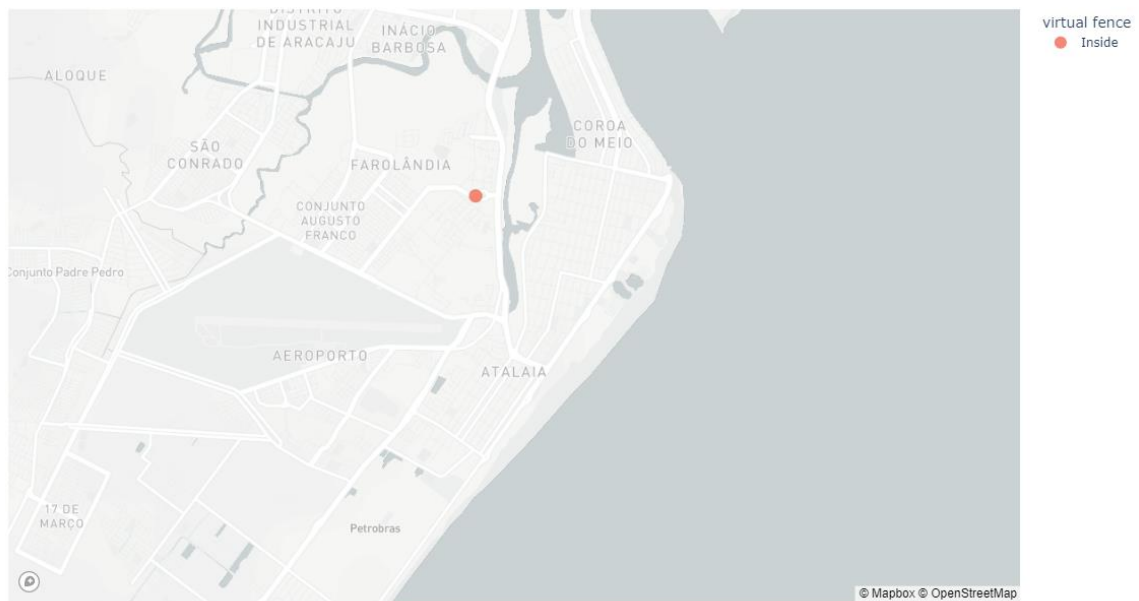
```

```
size='track_id',
animation_frame='time',
size_max=10,
zoom=12,
width=1200,
height=800)
px.scatter_mapbox(gdf[gdf["track_id"]== 38024],
lat="latitude",
lon="longitude",
color="virtual fence",
size='track_id',
animation_frame='time',
size_max=10,
zoom=12,
width=1200,
height=800)
```

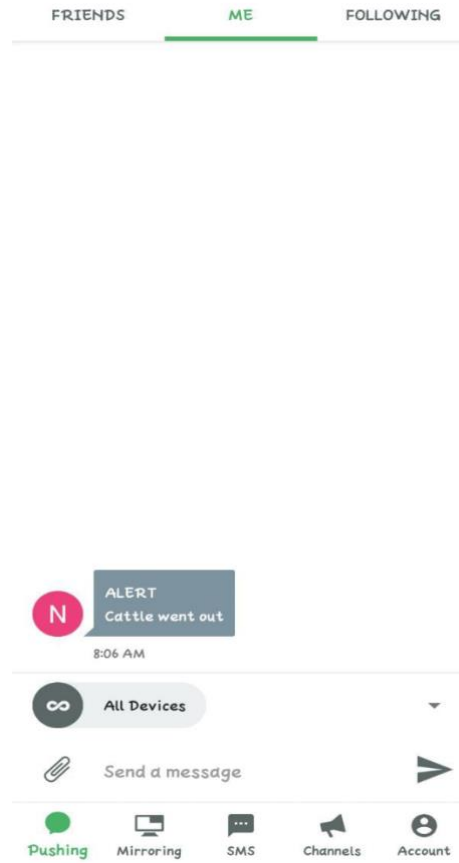
## B. SCREENSHOTS



***Fig: Outside the fence***



***Fig: Inside the fence***



***Fig: Screenshot of the alert message***

## C. RESEARCH PAPER

# VIRTUAL FENCE TO PROTECT LIVESTOCK

Kanika M S <sup>1</sup>, Neha V <sup>2</sup>, R M Joany <sup>3</sup>

Department of Electronics and Communication Engineering,  
Sathyabama Institute of Science and Technology,  
Chennai, India

[kani29062002@gmail.com](mailto:kani29062002@gmail.com) , [sweeneha60@gmail.com](mailto:sweeneha60@gmail.com), [joany.ece@sathyabama.ac.in](mailto:joany.ece@sathyabama.ac.in)

**Abstract** - This project involves the development of a virtual fence system to safeguard livestock from straying into fields and causing damage. Currently, farmers spend a lot of time and money manually patrolling their fields to prevent such invasions. The objective of this project is to reduce the need for manual intervention by implementing a system that uses technology to monitor the field and keep livestock within the designated boundaries. The proposed system involves the installation of nodes in the field that are equipped with Arduino Uno, PIR sensor, vibration sensors, sound generating devices, and Bluetooth module. Livestock crossing the boundary of the farm field can be detected using the PIR sensor, while the vibration sensor can detect any movement caused by the livestock. These sensors' responses can be displayed on an LCD screen, and farmers can be alerted to the presence of livestock using a smartphone app with GPS capabilities. The system can generate audio warnings and virtual barriers to keep the livestock within the designated area. The virtual fence can be designed in any geometrical shape, providing flexibility to farmers.

## I. INTRODUCTION

Livestock farming involves raising and domesticating animals for their meat, skin, wool, milk, and other products. However, animal management can be expensive for farmers, and physical fencing can be impractical in certain areas. Virtual fencing, which uses sensory cues to control livestock movement without physical or fixed boundaries, offers a solution. This technology employs a collar device that tracks the location of the livestock and emits an audio warning when it approaches a virtual boundary. This system can save ranchers time and money by reducing the need for physical or electrical fencing. Additionally, virtual fencing is an animal-friendly option that allows for more flexibility in managing livestock. The technology has been developed and optimized over several years to minimize the effect on the livestock

wearing the collars, and the first commercially available virtual fencing system was introduced in 2017. Virtual fencing has the potential to revolutionize livestock management by enabling farmers to move their animals more efficiently and effectively. Over the past few decades, virtual fencing technology has been optimized and refined to reduce labor, improve cattle management, and protect sensitive areas. The first patent for a virtual fencing system was granted in the United States in 1973. Since then, the technology has been tested and developed for over 20 years, with a livestock-specific virtual fencing system becoming commercially available in 2017. The system involves a GPS collar worn by the animal that tracks its location and position, and emits an RF signal with an audio warning when the animal approaches a virtual boundary set by the rancher. The audio warning increases in intensity and tone as the animal gets closer to the border, and is repeated two more times if the animal fails to respond. The rancher receives push messages on an LCD about the location of the animal.

Roughly one-third of the world's land is used for grazing, which cannot be utilized for crop production. The land that is used for grazing plays a crucial role in food production and helps in the incorporation of organic compounds if it is grazed properly. However, much of this grazing land is located in remote areas and has irregular shapes, making it difficult to manage. Due to the low production level of these lands, a large number of pastures are required, and livestock often has to move from one field to another. Fencing all these marginal pastures can be extremely costly in terms of labor, leaving farmers with the options of either herding the animals or exploring modern alternatives like virtual fencing.

## II. RELATED WORK

When the livestock approaches the first warning zone, the collar emits a low-intensity audio warning signal. If the livestock continues to move towards the second warning zone, the audio signal increases in intensity and is repeated three times. If the livestock still continues to move towards the boundary, a small electric pulse is emitted to the collar to deter the animal from crossing the boundary. This pulse is not harmful to the animal and has been tested to ensure that it is safe and effective.

Virtual fencing technology is still a relatively new concept, and there are ongoing research efforts to optimize and improve the technology. The benefits of virtual fencing include reduced labor costs for farmers, improved animal welfare by avoiding the use of physical fences, and the ability to manage grazing behavior more effectively. As the demand for meat and other animal products continues to grow, virtual fencing may become an increasingly important tool for livestock farmers.

Additionally, if the livestock enters the second warning zone, the collar emits an audio warning to the animal to indicate that it is approaching the boundary of the field. If the animal does not respond and continues to move towards the boundary, the intensity and tone of the audio warning increases until it reaches the maximum level. If the animal still does not respond, the cycle of the 10-second audio warning is repeated two more times.

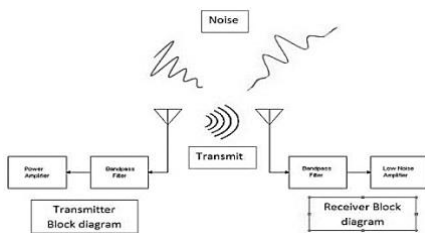


Fig. 1. Block diagram for first warning zone

The virtual fence system can be set up and programmed by the farmer to suit their specific needs. It provides a more flexible and cost-effective alternative to physical or electrical fencing. It also offers benefits such as reduced labour costs,

improved livestock management, and protection of sensitive areas.

The purpose of the virtual fire is to create a visual barrier that the livestock will perceive as a physical barrier, thus deterring them from crossing into the second warning zone. The combination of the audio warning and virtual fire provides a strong and effective signal to the livestock to prevent them from crossing the virtual boundary. The Arduino UNO is programmed to control the activation and deactivation of the LEDs and buzzers based on the inputs from the sensors. This system allows for a flexible and cost-effective way of controlling livestock grazing behavior without the need for physical or fixed fences. It also improves the welfare of livestock can move more freely and naturally within grazing area.

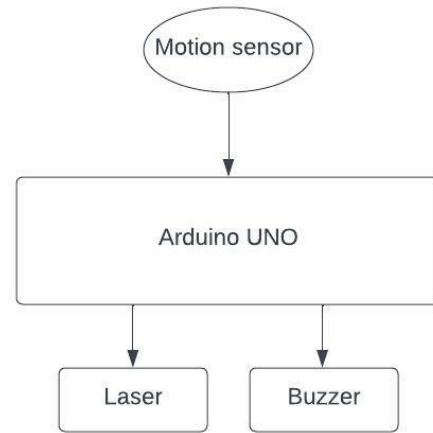


Fig. 2. Block diagram for second warning zone

## III. SYSTEM ARCHITECTURE

The virtual fence system can help livestock farmers control their animals' grazing behavior without the need for physical fences. By using RF technology, the system can create virtual boundaries around the grazing area and use various responses to deter the animals from leaving or entering the field. This can help reduce labor costs and improve the management of the livestock. Additionally, it can help protect the environment by minimizing the need for physical fencing and reducing the negative impact of overgrazing on the land. The RFID tag, which is attached to the collar worn by the cattle, communicates with the virtual fence and triggers an

audio warning and notifications to the rancher's mobile device when the cattle enters or exits the boundary of the field. This helps the rancher keep track of their livestock and ensure they stay within the designated grazing area. Virtual fences for livestock use various communication technologies such as GPS, RFID, Wi-Fi, or cellular data to track the location of livestock and monitor their behavior in the field. The use of GPS and RFID technology allows for accurate tracking and monitoring of livestock movement, while Wi-Fi and cellular data can be used to transmit data and receive alerts when an animal crosses a virtual boundary. By utilizing these communication technologies, virtual fences can effectively replace traditional physical fences and provide a more flexible and cost-effective solution for managing livestock grazing behavior. The power source should be capable of supporting the system for an extended period of time without the need for frequent recharging or replacement. Finally, the system requires software components, such as a database to store and manage the GPS and RFID data, a web interface for the rancher to monitor and control the virtual fence, and a notification system to send alerts to the rancher's mobile device when an animal crosses the virtual boundary. These software components can be developed using programming languages such as Python, and various libraries and frameworks.

The proposed system requires a variety of hardware and software components that work together to provide an effective virtual fence solution for livestock management. It's essential to ensure that all the components are compatible and work seamlessly to achieve the desired functionality.

The steps involved in setting up a virtual fence using Python libraries in Google Colab. Installing the necessary libraries and unzipping the GPS trajectory dataset are the first steps. Then, the data frame is converted into a geo dataframe to perform virtual fencing. This involves plotting a polygon using the geopandas library and using the point in polygon (PIP) method to check whether GPS points associated with a specific cattle (identified by its track id) are inside the polygon or not. If the GPS points are found to be outside the polygon, an audio warning is emitted and a notification is triggered to the rancher's mobile number via the pushbullet library.

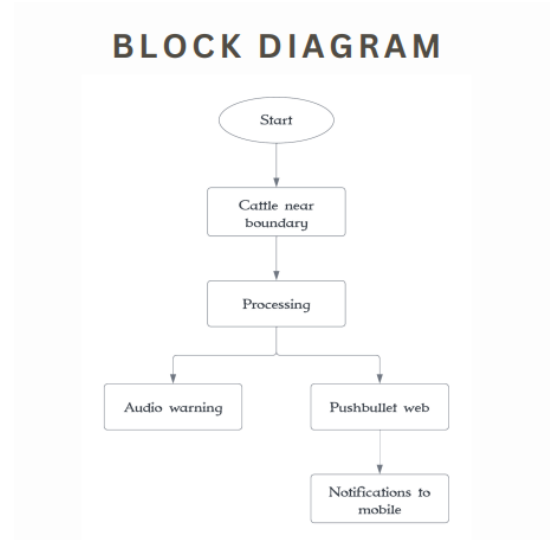


Fig. 3. Block diagram of virtual fence

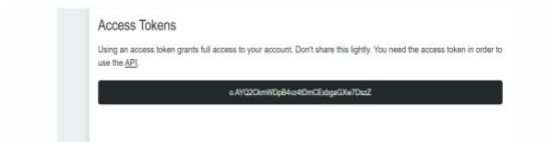


Fig. 4. Screenshot of the access token

That sounds like a good implementation of push notifications using Pushbullet to alert the rancher when the cattle move out of the virtual fence. Pushbullet is a popular tool for sending push notifications, and it can be easily integrated with Python code using the Pushbullet API.

Additionally, the system can help to prevent overgrazing, which can lead to soil erosion and reduced biodiversity in the grazing area. Overall, the proposed system provides an innovative and sustainable solution for managing livestock grazing behavior. The proposed virtual fence system for livestock management provides a flexible and cost-effective solution. The system utilizes communication technologies such as GPS, RFID, Wi-Fi, or cellular data to monitor the location and behavior of livestock and create a virtual boundary to manage grazing behavior.

By using virtual fencing instead of physical fencing, the system reduces the cost and environmental impact of installing and maintaining physical fences. Additionally, the system can help to prevent

overgrazing, which can lead to soil erosion and reduced biodiversity in the grazing area. Overall, the proposed system provides an innovative and sustainable solution for managing livestock grazing behavior.

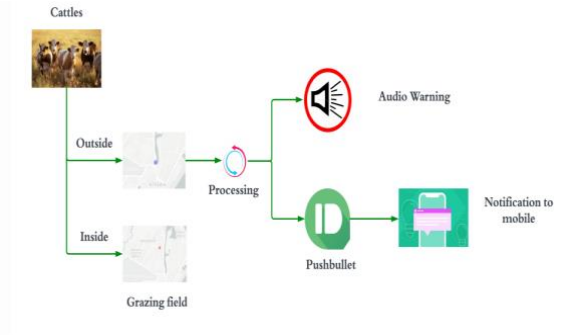


Fig. 5. Architecture of virtual fence to protect livestock



Fig. 6. Screenshot of the alert message

By setting up an account on the Pushbullet website, the user can obtain an access token that can be used

to authenticate API requests. Once the Pushbullet library is installed and the access token is obtained, the Pushbullet API can be used to create an instance and send notifications to the registered mobile device using the **push\_note** function.

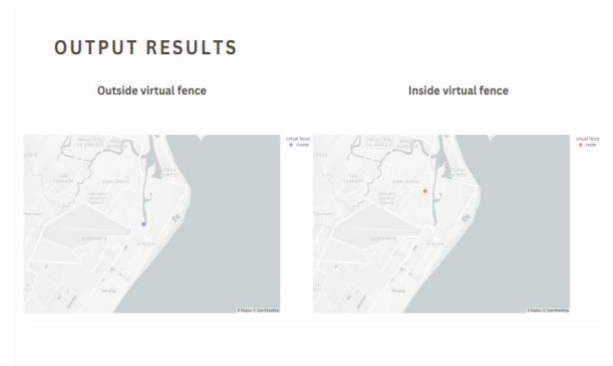
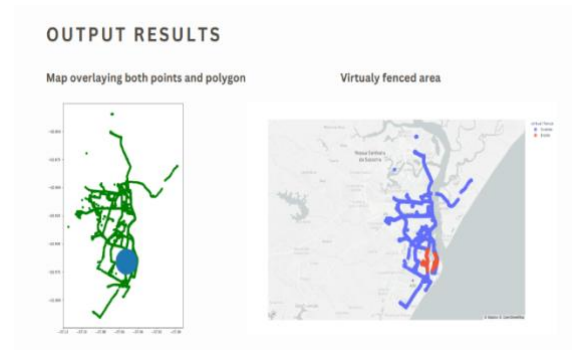


Fig. 7. Screenshot of the output results

## IV. CONCLUSION

The virtual fence can help prevent overgrazing in certain areas by limiting the amount of time that animals spend in specific locations. This can help improve the overall health of the pasture and reduce erosion. The system can also be useful for detecting and deterring predators from entering the field and attacking the livestock. Overall, the use of a virtual fence can be a cost-effective and efficient solution for managing livestock and ensuring their safety while grazing. It is important to consider the natural behavior of the cattle when using virtual fencing technology to ensure its effectiveness. In the case of intensive grazing regimes, it may be necessary to train the cattle to virtual fencing in a dedicated paddock. Additionally, some cattle may be more likely to breach the virtual fence, so it is important to accommodate their natural behavior. The minimum distance required to keep adjacent groups

of grazing cattle separated using virtual fencing requires further research. It is also important to note that virtual fencing should not be used to manage cattle that have close visual contact with other groups, particularly if they have previously been housed as a single group. While the experimental design produced some motivation for heifers to cross the virtual boundary, there are valuable learnings that can be applied to support the successful application of virtual fencing technology in grazing systems. Overall, virtual fencing technology offers many benefits in terms of flexibility and efficiency, but it is important to consider the specific needs and behaviors of the animals being managed.

## REFERENCES

- [1] R.-W. Bello, and O.M Moradeyo 2019. Monitoring Cattle Grazing Behavior and Intrusion Using Global Positioning System and Virtual Fencing. *Asian.J Math. Sci.*, 3(4): pp4-14.
- [2] Z.Butler Corke, R. Peterson and D. Rus From robots to animals: “virtual fences for controlling cows”. *International Journal of Robotics Research*, vol25, pp485–508,2006.
- [3] M.F.M Firdhouse, “IoT enhanced smart laserfence for reducing human elephant conflicts”, *International Conference of Information Technology and Research*, vol.2, issue,4,2020
- [4] Jung Kyu Park, Eun Young Park, Jaeho Kim, “Unmanned farm utilizer virtual fence technology for animal tracking”,*International Journal of Engineering and Advanced Technology*,vol.9,issue.2,2019, pp1328-1330
- [5] C. Lee, Henshall, J.M. Wark, T.J. Crossman, C.C. Reed, M.T. Rewer, H.G. Grady, J. Fisher, Associative learning by cattle to enable effective and ethical virtual fences. *Appl. Anim. Behav. Sci.* 2009, vol119, pp15–22.