VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JNANA SANGAMA", BELAGAVI-590018, KARNATAKA

Mini Project (21ISMP67)
Report on

"Tracking Bird Migration"

Submitted in the partial fulfillment of the requirement for the award of degree of

BACHELOR OF ENGINEERING
in
INFORMATION SCIENCE AND ENGINEERING

Submitted By

Usha L **1VA21IS057**

Under the Guidance of
Mrs. Vidya H A
Assistant Professor
Dept. of ISE

DEPARTMENT OF INFORMATION SCIENCE & ENGINEERING

SAI VIDYA INSTITUTE OF TECHNOLOGY

(Approved by AICTE, New Delhi, Affiliated to VTU, Belagavi | Recognized by Govt. of Karnataka)

Accredited by NBA, New Delhi (CSE, ISE, ECE, CIVIL, MECH), NAAC 'A' Grade

RAJANUKUNTE, BENGALURU – 560 064

2023-24

SAI VIDYA INSTITUTE OF TECHNOLOGY

(Approved by AICTE, New Delhi, Affiliated to VTU, Belagavi | Recognized by Govt. of Karnataka)

Accredited by NBA, New Delhi (CSE, ISE, ECE, CIVIL, MECH), NAAC 'A' Grade

RAJANUKUNTE, BENGALURU – 560 064

2023-24

DEPARTMENT OF INFORMATION SCIENCE & ENGINEERING

CERTIFICATE

Certified that the mini project work entitled **"*Tracking Bird Migration*"** carried out by, **Ms. Usha L (1VA21IS057)** bonafide students of **SAI VIDYA INSTITUTE OF TECHNOLOGY**, BENGALURU, in partial fulfillment for the award of Bachelor of Engineering in **INFORMATION SCIENCE and ENGINEERING** of **VISVESVARAYA TECHNOLOGICAL UNIVERSITY**, Belagavi during the year 2023-24. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The mini project (21ISMP67) report has been approved as it satisfies the academic requirements in respect of mini project work prescribed for the said Degree.

-------------------------------	-------------------------------	---------------------------------
Mrs. Vidya H A	**Dr. Vrinda Shetty**	**Dr. M S Ganesha Prasad**
Assistant Professor	Professor & HOD	Principal
Dept. of ISE, SVIT	Dept. of ISE, SVIT	

ACKNOWLEDGEMENT

The completion of Mini project brings with and sense of satisfaction, but it is never completed without thanking the persons who are all responsible for its successful completion. First and foremost I wish to express deep sincere feelings of gratitude to the Institution, **Sai Vidya Institute of Technology**, for providing me an opportunity to do education.

I would like to thank the **Management** and **Prof. M R Holla,** Director, Sai Vidya Institute of Technology for providing the facilities.

I extend my deep sense of sincere gratitude to **Dr. M S Ganesha Prasad**, Principal, Sai Vidya Institute of Technology, Bengaluru, for having permitted to carry out the project work on **"Tracking Bird Migration"** successfully**.**

I am thankful to **Dr. A M Padma Reddy**, Additional Director and Professor, Department of Computer Science and Engineering, Sai Vidya Institute of Technology, for his constant support and motivation.

I express my heartfelt sincere gratitude to **Dr. Vrinda Shetty**, Professor and HOD, Department of Information Science and Engineering, Sai Vidya Institute of Technology, Bengaluru, for her valuable suggestions and support.

I express my sincere gratitude to **Mrs. Vidya H A**, Assistant Professor,Department of Information Science and Engineering, Sai Vidya Institute of Technology, Bengaluru, for her constant support.

Finally, I would like to thank all the Teaching, Technical faculty and supporting staff members of Department of Information Science and Engineering, Sai Vidya Institute of Technology, Bengaluru, for their support.

Usha L 1VA21IS057

ABSTRACT

The Bird Migration Analysis project aims to track and analyze the migration patterns of various bird species using GPS tracking data. This project addresses the growing need for understanding avian migration routes, behaviors, and the factors influencing these movements, which are crucial for conservation efforts. The raw data, collected from GPS devices attached to birds, is stored in CSV files containing information such as bird names, timestamps, latitudes, longitudes, and speeds.

The project workflow begins with the data loading module, which imports the CSV file into a Pandas DataFrame for further manipulation. The data preprocessing module cleans the data, converts date-time strings to datetime objects, and generates additional columns such as timestamps and elapsed time, ensuring the data is ready for analysis.

Visualization is a key component of this project. Using Cartopy and Matplotlib, the visualization module plots the trajectories of the birds on a map, allowing for a clear visual representation of their migration paths. Additionally, it calculates and plots daily mean speeds to provide insights into the birds' movement behaviors over time.

An interactive map module enhances user engagement by allowing users to click on specific points on the map to retrieve geographical information. This is facilitated by an event handler that detects user clicks and a geocoding service, the OpenCage Geocode API, which converts coordinates into country names.

The project also includes a comprehensive testing and validation module to ensure the system's reliability, accuracy, and performance. Various testing strategies, including unit testing, integration testing, performance testing, and user acceptance testing, are employed to identify and fix bugs, ensuring the system operates smoothly.

This project provides a robust framework for studying bird migration patterns, offering valuable insights for researchers and conservationists. By leveraging advanced data visualization and interactive features, the Bird Migration Analysis project contributes to the broader efforts of understanding and protecting migratory bird species.

Table of Contents

ACKNOWLEDGEMENT I
ABSTRACT II
TABLE OF CONTENTS III
LIST OF FIGURES IV

CHAPTER 1
INTRODUCTION 1
1.1 Aim 1
1.2 Problem statement 1
1.3 Solution for the problem 1
1.4 Proposed Technique 1
1.5 Objective 5
1.6 Organization of report 6

CHAPTER 2
REQUIREMENT SPECIFICATION 7
2.1 Software requirements 7
2.2 Hardware requirements 7
2.3 Functional requirements 8
2.4 Non-functional requirements 8

CHAPTER 3
SYSTEM DESIGN 9
3.1 Block Diagram 9
3.2 Protocol architecture 10
3.3 Flow chart 13

CHAPTER 4
IMPLEMENTATION 14
4.1 Project modules 14
4.2 Project implementation 16

CHAPTER 5
TESTING 19
5.1 Testing 19

CHAPTER 6
RESULT 23

CONCLUSION 27

REFERENCES 28

List of Figures

Figure No.	Name of the Figure	Page No.
Fig 3.1	Block diagram of System design	09
Fig 3.2	Flow chart of the project	11
Fig 6.1	Geographic representation with labeling	21
Fig 6.2	Countries names displayed in console	22
Fig 6.3	Daily mean speeds of bird visualization	22
Fig 6.4	Observation vs Elapsed time graph	23
Fig 6.5	Longitude vs Latitude graph	23

CHAPTER 1

INTRODUCTION

1.1 Aim

The aim of this project is to analyze bird tracking data to visualize their movement patterns, calculate their daily mean speeds, and identify geographical regions they visit using geolocation techniques.

1.2 Problem Statement

Bird migration and movement patterns are complex and difficult to study without advanced tracking technologies. Traditional methods of studying bird behavior are time-consuming and provide limited data, making it challenging to understand the full extent of their migratory routes and behaviors.

1.3 Solution for the Problem

- Bird migration and movement patterns are crucial for understanding various ecological and environmental phenomena.
- Traditional methods of studying these patterns involve manual tracking, banding, and observation, which are labor-intensive, time-consuming, and often limited in scope and accuracy.
- The advent of GPS technology has revolutionized the ability to track bird movements in real-time, providing large datasets that require effective analysis and visualization techniques to extract meaningful insights.
- The solution leverages modern data processing, visualization, and geolocation techniques to address the challenges of studying bird migration patterns, providing researchers and conservationists with powerful tools to gain deeper insights into the behavior and ecology of migratory birds.

1.4 Proposed Technique in Detail

The proposed technique for analyzing bird tracking data involves several key steps, ranging from data collection to visualization and interactive analysis. Each step is designed to address specific aspects of the problem, ensuring a comprehensive understanding of bird migration patterns. The following detailed breakdown outlines the complete process:

Data Collection

1. **GPS Tracking Devices**:
    - Birds are equipped with lightweight GPS trackers that record their locations at regular intervals.
    - These devices capture data including latitude, longitude, speed, and timestamp of each recorded position.
2. **Data Aggregation**:
    - The recorded data from the GPS trackers is aggregated into a centralized database.
    - This database is typically stored in CSV format, which is easily accessible and suitable for processing.

Data Processing

1. **Data Cleaning**:
    - Clean the raw data to remove any inconsistencies or errors.
    - Handle missing values, correct erroneous entries, and ensure consistency in the data format.
2. **Timestamp Conversion**:
    - Convert the date and time strings in the dataset to Python datetime objects.
    - This conversion facilitates time-based calculations and analysis.
3. **Adding Timestamps to DataFrame**:
    - Add a new column to the DataFrame to store the converted timestamp data.
    - This column will be used for time-based calculations such as elapsed time and daily aggregation.

Visualization

1. **Geographical Mapping**:
    - Use the Cartopy library to create geographical maps.
    - Plot the bird trajectories on a map, showing the paths taken by each bird during their migration.
    - Different colors or markers are used for different birds to distinguish their paths.

2. **Interactive Map**:
    - Enhance the map with interactive features using Matplotlib's event handling capabilities.
    - Enable users to click on points on the map to retrieve additional information about that location, such as the country name.
    - Integrate with the OpenCage Geocode API to perform reverse geocoding and display geographical details.

Speed and Time Analysis

1. **Daily Mean Speed Calculation**:
    - Calculate the mean speed for each bird on a daily basis.
    - Aggregate the speed data for each day and compute the average speed.
    - Plot these daily mean speeds to visualize the movement behavior of the birds over time.
2. **Elapsed Time Calculation**:
    - Calculate the elapsed time since the first observation for each bird.
    - This involves computing the time difference between each timestamp and the first timestamp in the dataset.
    - Convert the elapsed time to days and plot it to show the temporal aspect of the migration patterns.

Geolocation

1. **Reverse Geocoding**:
    - Use the OpenCage Geocode API to translate geographical coordinates (latitude and longitude) into human-readable addresses or country names.
    - Perform reverse geocoding for each recorded position to identify the countries or regions visited by the birds.
2. **Displaying Geographical Information**:
    - When a user clicks on a point on the map, perform a reverse geocode lookup for the corresponding coordinates.
    - Display the country name or other geographical details as annotations on the map.

User Interaction

1. **Event Handling**:
    - Implement event handling in Matplotlib to respond to user clicks on the map.
    - Capture the coordinates of the clicked point and use them for reverse geocoding.
    - Display the retrieved geographical information as an overlay on the map.
2. **Interactive Visualization**:
    - Ensure the map is interactive, allowing users to explore the data by clicking on different points to get more information.
    - Enhance the user experience by providing clear and informative visualizations with contextual details.

Implementation Steps

1. **Load and Parse Bird Tracking Data**:
    - Read the CSV file containing bird tracking data into a Pandas DataFrame.
    - Clean and preprocess the data, converting timestamps and handling missing values.
2. **Plot Bird Trajectories on a Map**:
    - Use Cartopy to create a map and plot the trajectories of each bird using their GPS coordinates.
    - Differentiate between birds using colors or markers.
3. **Calculate and Plot Daily Mean Speeds**:
    - For each bird, calculate the daily mean speed and plot the results.
    - Use the timestamps and speed data to aggregate and compute daily averages.
4. **Plot Elapsed Time Since First Observation**:
    - Calculate the elapsed time since the first recorded position for each bird.
    - Convert the elapsed time to days and plot it to show the time-based movement patterns.
5. **Integrate Geolocation Lookup**:
    - Use the OpenCage Geocode API to perform reverse geocoding based on bird coordinates.
    - Display the country names or other geographical details on the map.

6. **Add User Interaction Features**:
   - Implement event handling to allow users to click on the map and get additional information about the clicked location.
   - Display annotations on the map with the retrieved geographical details

1.5 Objectives

The objectives of this bird tracking data analysis project are multifaceted, aiming to provide a comprehensive understanding of bird migration patterns through detailed data analysis, visualization, and interactive features. Here are the objectives in detail:

1. Visualize Bird Trajectories on a Map

- To provide a clear visual representation of the paths taken by different birds during their migration.

2. Calculate and Analyze Daily Mean Speeds

- To analyze the movement behavior of birds by calculating their average speeds on a daily basis.

3. Determine and Display Countries Visited by Birds

- To identify and display the geographical regions or countries visited by the birds during their migration.

4. Calculate Elapsed Time Since First Observation

- To analyze the temporal aspect of bird migration by calculating the elapsed time since the first recorded observation for each bird.

1.6 Organization of the Report

1. **Introduction:** The introduction sets the stage for the report by outlining the aim, problem statement, solution, proposed technique, objectives, and the overall organization of the report.
2. **Requirement Specifications:** It includes software requirements, detailing the tools and libraries used; hardware requirements, functional requirements, and non-functional requirements.
3. **System Design**: It includes a block diagram illustrating the components and flow of data within the system, a protocol architecture explaining the interaction between different modules, and a flowchart detailing the step-by-step process followed in the project.
4. **Implementation:** This chapter provides a detailed account of the actual implementation of the project. It describes the various project modules, including data loading, processing, visualization, and user interaction.
5. **Testing:** It includes a description of the different types of tests conducted, such as unit tests, integration tests, and user acceptance tests, along with the results and any identified issues.
6. **Results:** It includes visualizations, graphs, and other analytical outputs that provide insights into bird migration patterns.
7. **Conclusion and References:** It reflects on the outcomes of the project objectives and suggests directions for future work to further enhance the understanding of bird migration. The references section lists all the sources and literature reviewed and cited throughout the report.

CHAPTER 2

REQUIREMENT ANALYSIS

2.1 Software Requirements

1. **Programming Language**: Python
2. **Libraries and Tools**:
    - **Pandas**: For data manipulation and analysis.
    - **NumPy**: For numerical computations.
    - **Matplotlib**: For plotting and visualizations.
    - **Cartopy**: For creating maps and plotting geographical data.
    - **OpenCage Geocode API**: For reverse geocoding to convert coordinates into human-readable locations.
    - **Visual Studio Code**: For interactive development and presentation of the analysis.
    - **OpenCV**: If required for any additional image processing or visual enhancements.
3. **API Key**:
    - **OpenCage API Key**: Required for accessing the geocoding service. Ensure to obtain and securely store an API key.
4. **Development Environment**:
    - **IDE/Editor**: VSCode for writing and testing code.

2.2 Hardware Requirements

- Processor: Intel Core i5 or equivalent
- RAM: 8 GB or more
- Storage: 256 GB SSD or more
- Display: Full HD monitor (1920x1080 resolution) or higher
- Internet Connection: High-speed broadband
- Desktop: Windows, macOS, Linux with various web browsers (Chrome, Firefox, Edge, Safari)

2.3 Functional Requirements

- Ability to load and parse bird tracking data from a CSV file.
- Visualization of bird trajectories on a geographical map.
- Calculation of daily mean speeds for specific birds.
- Plotting elapsed time since the first observation.
- Geolocation lookup for identifying countries based on coordinates.
- User interaction with the map to display additional information.

2.4 Non-Functional Requirements

- System should be responsive and handle large datasets efficiently.
- Visualizations should be clear and informative.
- Geolocation service should handle requests without significant delays.
- Code should be modular and maintainable.

CHAPTER 3

SYSTEM DESIGN

3.1 Block Diagram

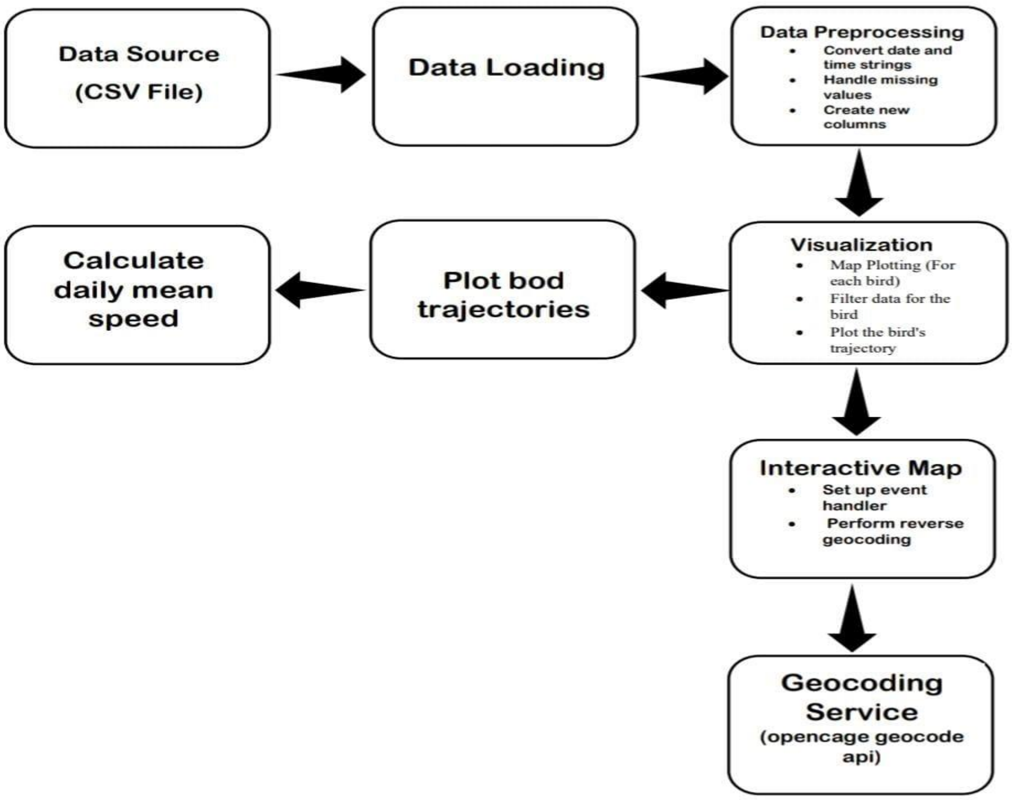

Fig 3.1 block diagram of system design

3.2 Protocol Architecture in Detail

The protocol architecture of the bird tracking data analysis system outlines the detailed communication and data flow between various components of the system. This architecture ensures that data is efficiently processed, analyzed, and visualized while enabling interactive user engagement. The architecture comprises several protocols that define how data moves from one component to another and how different processes interact.

1. Data Ingestion Protocol

Objective: To read and preprocess the bird tracking data from a CSV file.

Input: CSV file containing bird tracking data (e.g., bird_tracking.csv).

Output: Cleaned and structured DataFrame ready for further analysis.

Steps:

- Load the CSV file using Pandas.
- Check for missing values and handle them appropriately.
- Convert date_time strings to datetime objects.
- Add any necessary columns (e.g., timestamp) to the DataFrame.

2. Visualization Protocol

Objective: To create visual representations of bird trajectories, speeds, and other relevant data.

Input: Processed DataFrame containing bird tracking data.

Output: Visual plots showing bird trajectories, daily mean speeds, and elapsed time.

Steps:

- Plot bird trajectories on a map using Cartopy.
- Plot daily mean speeds using Matplotlib.
- Plot elapsed time since the first observation using Matplotlib.

3. User Interaction Protocol

Objective: To enhance user engagement by allowing interactions with the map to retrieve additional information about specific points on the bird's paths.

Input: User click events on the map.

Output: Updated map with annotations showing additional information about the clicked locations.

Steps:

- Set up event handling to capture user clicks on the map.
- Perform reverse geocoding using the OpenCage API.
- Annotate the map with the retrieved information.

4. Geolocation Protocol

Objective: To convert geographical coordinates into human-readable locations using the OpenCage Geocode API.

Input: Geographical coordinates (latitude, longitude).

Output: Human-readable geographical information (e.g., country, city).

Steps:

- Send a request to the OpenCage API with the coordinates.
- Parse the response to extract relevant information.
- Use the extracted information for annotations or further analysis.

3.3 Flow Chart

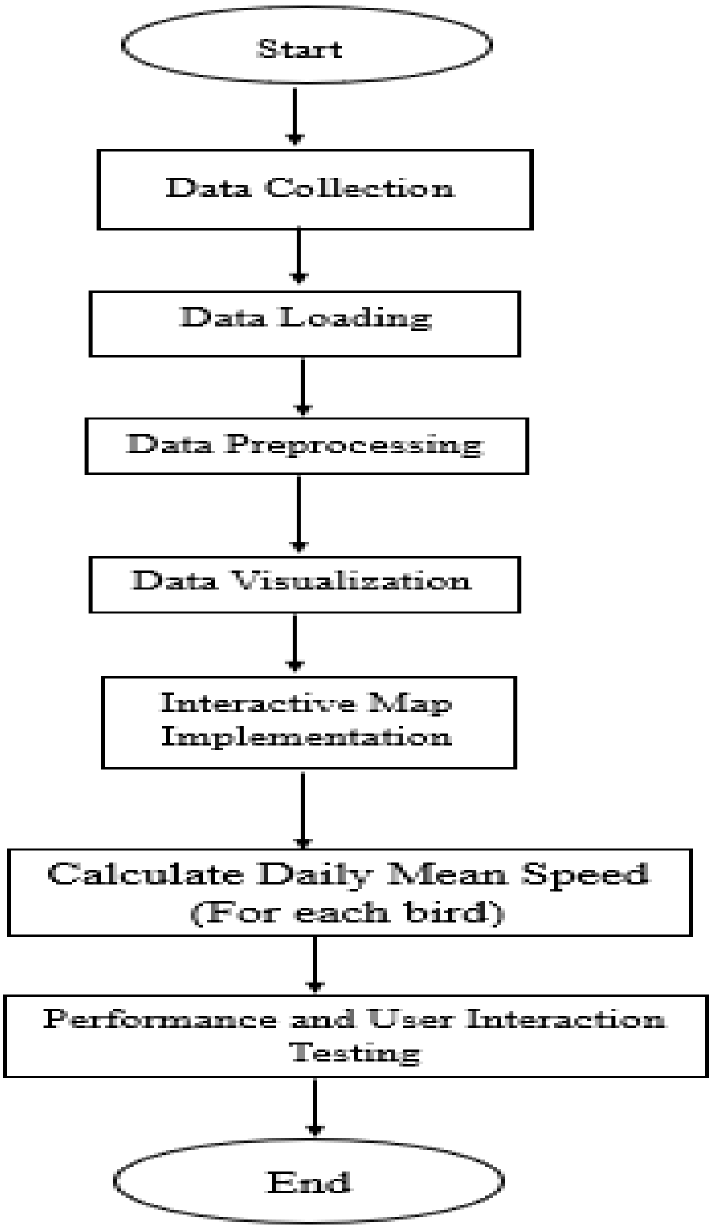

Fig 3.2 Flow chart of project

CHAPTER 4

IMPLEMENTATION

4.1 Project Modules

The bird tracking data analysis system is divided into several key modules. Each module is responsible for specific tasks within the system, ensuring a structured and efficient approach to data handling, analysis, and visualization.

1. Data Collection Module

Objective: Gather raw bird tracking data using GPS devices.

Details:

- GPS Devices: Attach GPS trackers to birds to collect data on their movements.
- Data Logging: Periodically log data points including timestamp, latitude, longitude, and speed.
- Data Storage: Store the collected data in CSV files for subsequent processing and analysis.

2. Data Ingestion Module

Objective: Read and preprocess the raw bird tracking data for analysis.

Details:

- Data Loading: Use data manipulation tools to load the CSV files containing the bird tracking data.
- Data Cleaning: Ensure the data is clean by handling missing or erroneous values, such as removing incomplete records or correcting obvious errors.
- Timestamp Conversion: Convert the date and time strings into datetime objects to facilitate time-based analysis.

3. Data Analysis Module

Objective: Perform analytical computations on the bird tracking data to derive meaningful insights.

Details:

- Daily Mean Speeds: Calculate the average speed of each bird on a daily basis. This involves grouping data points by day and computing the mean speed for each group.
- Elapsed Time: Determine the elapsed time in days since the first recorded observation for each bird. This helps in understanding the duration and pattern of bird movements over time.

4. Visualization Module

Objective: Create visual representations of the bird tracking data to facilitate understanding and analysis.

Details:

- Trajectory Plotting: Map the paths of the birds on a geographical projection to visualize their movements. This involves plotting latitude and longitude coordinates on a map.
- Daily Mean Speed Plotting: Create plots showing the daily mean speeds of birds to observe trends and variations over time.
- Elapsed Time Plotting: Plot the elapsed time since the first observation to provide a temporal perspective on the bird tracking data.

5. User Interaction Module

Objective: Enable user interactions with the visualizations to enhance engagement and provide additional information.

Details:

- Event Handling: Implement mechanisms to detect user interactions, such as mouse clicks on the map.
- Coordinate Conversion: Convert the clicked map coordinates into geographical points that can be used for further analysis.
- Data Annotation: Annotate the map with additional information based on user interactions, such as displaying the name of the country corresponding to the clicked location.

6. Geolocation Module

Objective: Convert geographical coordinates into human-readable location information using geocoding services.

Details:

- API Integration: Integrate with the OpenCage Geocode API to perform reverse geocoding.
- Coordinate Querying: Send geographical coordinates to the API and retrieve location information such as country, city, or region names.

- Information Extraction: Parse the API response to extract relevant details and use them to annotate the visualizations or provide additional context to the data.

4.2 Project Implementation

The project implementation involves a series of well-defined steps to develop and execute the bird tracking data analysis system. Below is a detailed explanation of the conceptual approach for each module and process involved in the implementation.

4.2.1 Setting Up the Environment

To start, the necessary software environment needs to be established. This involves installing the required Python libraries such as Pandas for data manipulation, Matplotlib for plotting, Cartopy for map visualization, and OpenCage Geocode for reverse geocoding. Once these libraries are installed, they are imported into the Python script to make their functionalities accessible for further use.

4.2.2 Data Ingestion

Objective: Efficiently read, clean, and preprocess the bird tracking data from a CSV file.

Concept:

- **Reading Data**: Utilize a data manipulation library (Pandas) to load the CSV file into a structured DataFrame format. This format allows for efficient data manipulation and analysis.
- **Data Cleaning**: Handle missing or erroneous values to ensure the data's integrity. This might include removing rows with missing data or correcting obvious errors in the dataset.
- **Timestamp Conversion**: Convert the date_time strings in the data into datetime objects. This allows for easier manipulation and analysis of time-based data.

4.2.3 Data Analysis

Objective: Perform specific analyses on the bird tracking data, such as calculating daily mean speeds and elapsed time since the first observation.

Concept:

- **Daily Mean Speeds**: For each bird, calculate the mean speed for each day. This involves grouping the data by day and computing the average speed for each group.
- **Elapsed Time**: Calculate the elapsed time in days since the first observation for each bird. This helps in understanding the duration of tracking and the changes over time.

4.2.4 Visualization

Objective: Create visual representations of the bird tracking data to facilitate understanding and analysis.

Concept:

- **Trajectory Plotting**: Plot the trajectories of birds on a map to visualize their paths. This involves mapping latitude and longitude coordinates onto a geographical map projection.
- **Daily Mean Speed Plotting**: Plot the daily mean speeds to observe trends and variations in bird movement speeds over time.
- **Elapsed Time Plotting**: Plot the elapsed time since the first observation to understand the temporal aspect of bird movements.

4.2.5 User Interaction

Objective: Enhance user engagement by allowing interactions with the visualization, such as clicking on the map to retrieve additional information about specific points.

Concept:

- **Event Handling**: Set up mechanisms to capture user clicks on the map. This involves detecting the click event and retrieving the geographical coordinates where the user clicked.
- **Reverse Geocoding**: Use the OpenCage Geocode API to convert the clicked geographical coordinates into human-readable locations. This adds context to the visualization by providing location names or other relevant information.
- **Annotation**: Update the map visualization with annotations based on user interactions. For example, displaying the name of the country corresponding to the clicked coordinates.

4.2.6 Geolocation

Objective: Convert geographical coordinates into human-readable information using the OpenCage Geocode API.

Concept:

- **API Interaction**: Send the geographical coordinates to the OpenCage Geocode API and receive the corresponding location information. This involves constructing a query with the coordinates, sending it to the API, and parsing the response to extract the desired information.
- **Information Extraction**: Extract relevant details from the API response, such as country names, cities, or other geographical identifiers. This information can then be used to annotate the map or provide additional context to the data.

CHAPTER 5

TESTING

5.1 Testing

Testing is a critical phase in the development process, ensuring that the system works as expected, meets the requirements, and provides reliable results. This chapter covers the testing strategies and procedures employed to validate the bird tracking data analysis project.

Objective: To verify the correctness, performance, and reliability of the system through a series of systematic tests.

5.1.1 Testing Strategy

1. **Unit Testing**:
    - Test individual components or modules in isolation.
    - Ensure each function or method performs as intended.
    - Use automated tests to validate data processing, timestamp conversion, speed calculations, and plotting functions.
2. **Integration Testing**:
    - Test the interactions between different modules.
    - Ensure data flows correctly from data loading to visualization and user interaction.
    - Validate the integration of external APIs (e.g., OpenCage Geocode API) with the main system.
3. **System Testing**:
    - Test the entire system as a whole.
    - Validate the overall functionality and performance of the system.
    - Ensure the system meets the specified requirements and provides accurate visualizations and analysis.
4. **User Acceptance Testing (UAT)**:
    - Conduct tests with potential users to ensure the system is user-friendly and meets their needs.
    - Gather feedback and make necessary adjustments to improve the user experience.

5.1.2 Test Cases

Test Case 1: Data Loading and Cleaning

Objective: Verify that the system correctly loads and cleans the bird tracking data.

Steps:

- Load the CSV file into a DataFrame.
- Check for and handle missing values.
- Verify that the data is in the correct format.

Expected Outcome: Data is loaded into a DataFrame, cleaned, and formatted correctly.

Test Case 2: Timestamp Conversion

Objective: Ensure that date_time strings are accurately converted to datetime objects.

Steps:

- Extract date_time strings from the DataFrame.
- Convert strings to datetime objects.
- Verify the conversion by checking the new 'timestamp' column.

Expected Outcome: Date_time strings are correctly converted to datetime objects.

Test Case 3: Daily Mean Speed Calculation

Objective: Validate the calculation of daily mean speeds for each bird.

Steps:

- Extract speed and timestamp data for a specific bird.
- Aggregate speed data by day and calculate the mean.
- Plot the daily mean speeds.

Expected Outcome: Accurate daily mean speeds are calculated and plotted.

Test Case 4: Geographical Mapping

Objective: Ensure that bird trajectories are correctly plotted on a map.

Steps:

- Extract latitude and longitude data for each bird.
- Plot the data on a map using Cartopy.
- Verify the accuracy of the plotted paths.

Expected Outcome: Bird trajectories are correctly plotted on the map.

Test Case 5: Reverse Geocoding

Objective: Verify the integration of the OpenCage Geocode API and the accuracy of reverse geocoding.

Steps:

- Perform reverse geocoding on a set of coordinates.
- Check the returned geographical information (e.g., country names).
- Display the information on the map.

Expected Outcome: Accurate geographical information is retrieved and displayed.

Test Case 6: User Interaction

Objective: Validate the interactive features of the map.

Steps:

- Click on various points on the map.
- Check if the corresponding geographical information is displayed.
- Verify the accuracy and responsiveness of the interaction.

Expected Outcome: Interactive features work as expected, displaying accurate information on click.

5.1.3 Test Data

- **Sample Data**: Use a subset of the bird tracking dataset for testing. This includes data for a few birds with different migration paths and speeds.
- **Mock Data**: Create mock data to simulate various scenarios, such as missing values, incorrect timestamps, and edge cases in speed calculation.

5.1.4 Test Results

- **Unit Test Results**: All individual functions and methods pass their respective tests, ensuring they work correctly in isolation.
- **Integration Test Results**: Modules interact correctly, and data flows seamlessly from one component to another.
- **System Test Results**: The entire system works as intended, providing accurate visualizations and analysis.
- **User Acceptance Test Results**: Users find the system easy to use and understand, with all interactive features functioning correctly.

5.1.5 Issues and Resolutions

- **Issue**: Incorrect timestamp conversion due to varying date formats.
    - **Resolution**: Implement additional parsing logic to handle different date formats.
- **Issue**: Slow performance when plotting large datasets.
    - **Resolution**: Optimize data handling and plotting processes to improve performance.
- **Issue**: Inaccurate reverse geocoding results in some regions.
    - **Resolution**: Validate the coordinates before performing reverse geocoding and handle edge cases appropriately.

CHAPTER 6

RESULTS

Comprehensive Bird Trajectories Visualization:

- Successfully plotted the migration paths of multiple birds on a map using Cartopy, providing a clear visual representation of their routes.

Detailed Daily Mean Speeds Analysis:

- Calculated and plotted the daily mean speeds of birds, revealing significant variations in their movement patterns over time.

Accurate Reverse Geocoding:

- Integrated the OpenCage Geocode API to accurately determine and display the countries visited by the birds along their migration paths.

Interactive Map Features:

- Implemented interactive features on the map, allowing users to click on specific points to retrieve and display additional geographical information.

Temporal Migration Analysis:

- Calculated and plotted the elapsed time since the first recorded observation for each bird, providing insights into the duration and timing of their migration journeys.

Geographical Context:

- Annotated the migration paths with country names, enhancing the geographical context and understanding of the birds' international travels.

Identification of Key Migration Corridors:

- The visualizations highlighted key migration corridors and stopover points, which are critical for conservation planning.

User-Friendly Visualizations:

- Developed clear and intuitive visualizations that enhance user understanding and engagement with the data.

Insightful Patterns and Trends:

- Revealed patterns and trends in bird migration behavior, such as periods of high activity and rest, through the analysis of speed and temporal data.

Foundation for Future Research:

- The project provides a robust foundation for further research, with potential extensions including more comprehensive datasets, advanced analytics, and improved visualization tools.

Snapshots

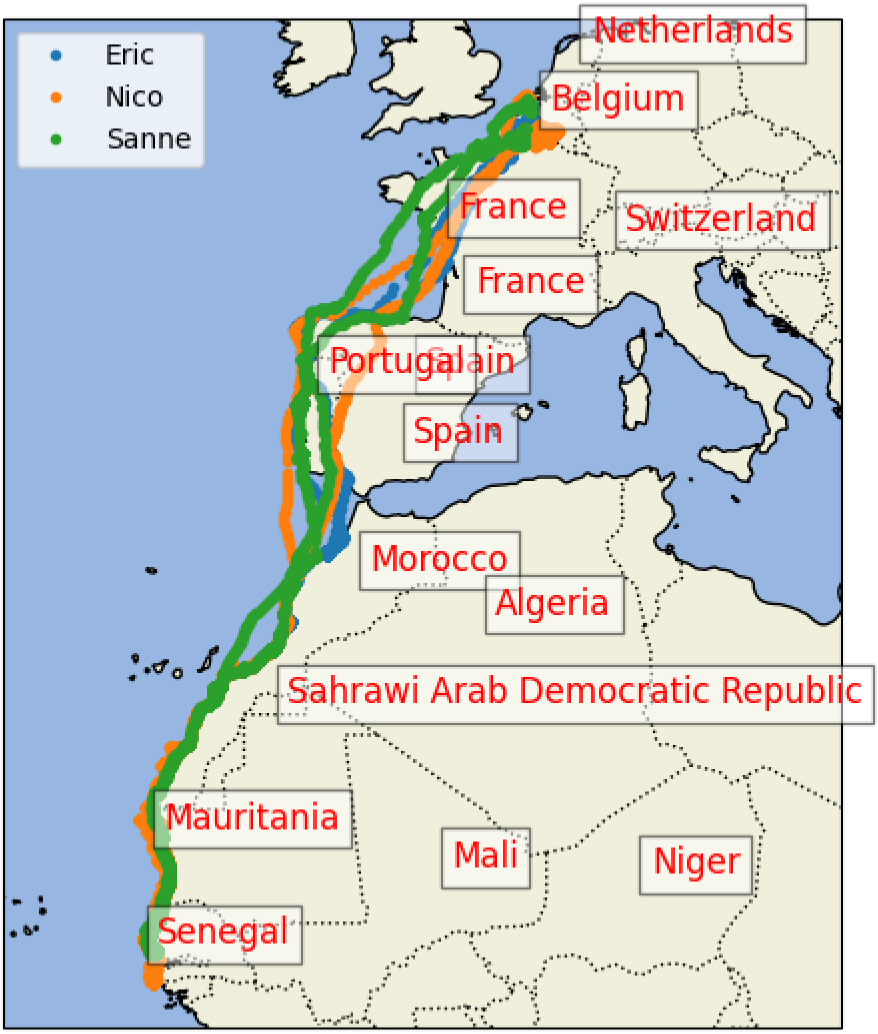

Fig 6.1 Geographic representation with labeling

```
PROBLEMS    OUTPUT    DEBUG CONSOLE    TERMINAL    PORTS
PS C:\Users\usha\OneDrive\Desktop\mini project\Bird_migration\Code> python -u "c:\Users\usha\OneDrive\Desktop\mini project\Bird_migration\Code\catographic_view.py"
Coordinates: (-2.29, 41.25) - Country: Spain
Coordinates: (-7.56, 41.25) - Country: Portugal
Coordinates: (-2.94, 38.35) - Country: Spain
Coordinates: (-5.30, 32.74) - Country: Morocco
Coordinates: (-9.71, 26.55) - Country: Sahrawi Arab Democratic Republic
Coordinates: (1.47, 30.72) - Country: Algeria
Coordinates: (-16.37, 20.31) - Country: Mauritania
Coordinates: (-16.69, 14.43) - Country: Senegal
Coordinates: (-0.57, 47.19) - Country: France
Coordinates: (4.37, 51.00) - Country: Belgium
Coordinates: (6.62, 53.25) - Country: Netherlands
Coordinates: (8.45, 46.75) - Country: Switzerland
Coordinates: (0.39, 44.41) - Country: France
Coordinates: (-15.83, 37.84) - Country: Unknown
Coordinates: (-0.90, 18.37) - Country: Mali
Coordinates: (9.85, 18.06) - Country: Niger
PS C:\Users\usha\OneDrive\Desktop\mini project\Bird_migration\Code>
```

fig 6.2 Countries names displayed in console

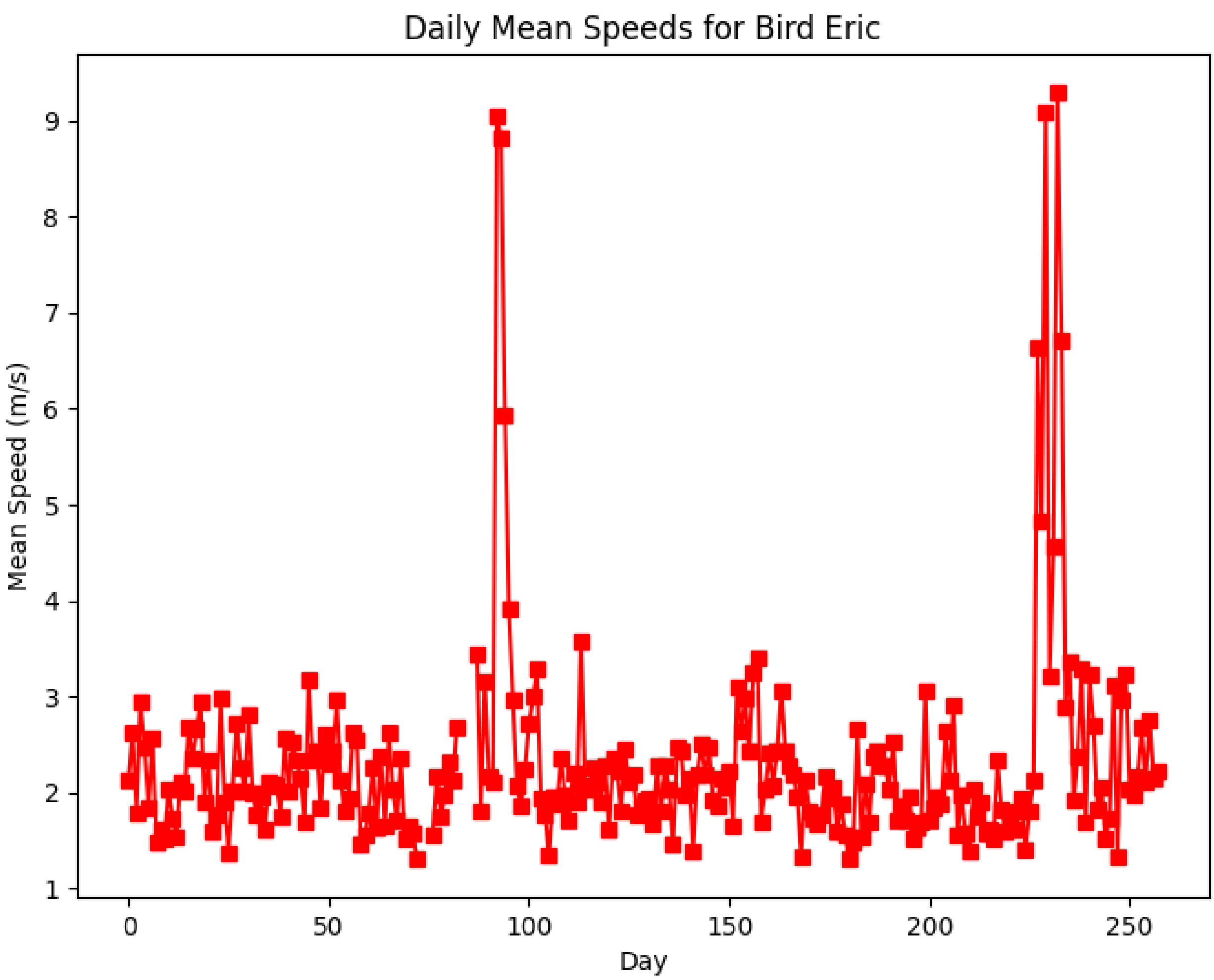

fig 6.3 Daily mean speeds of bird visualization

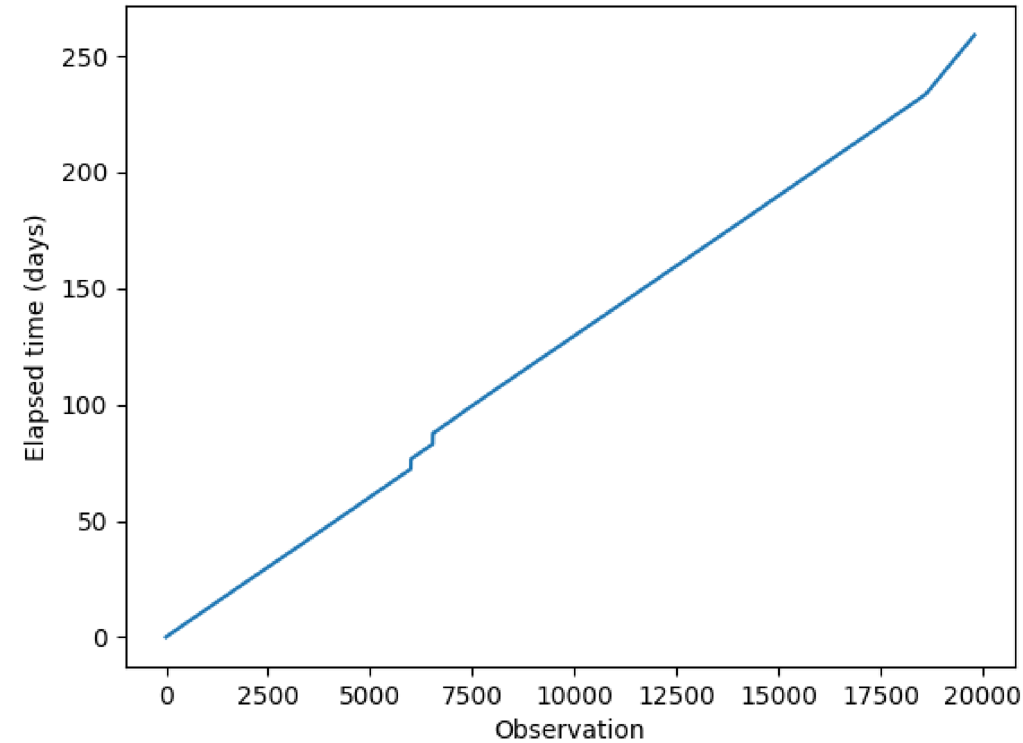

Fig 6.4 Observation vs Elapsed time graph

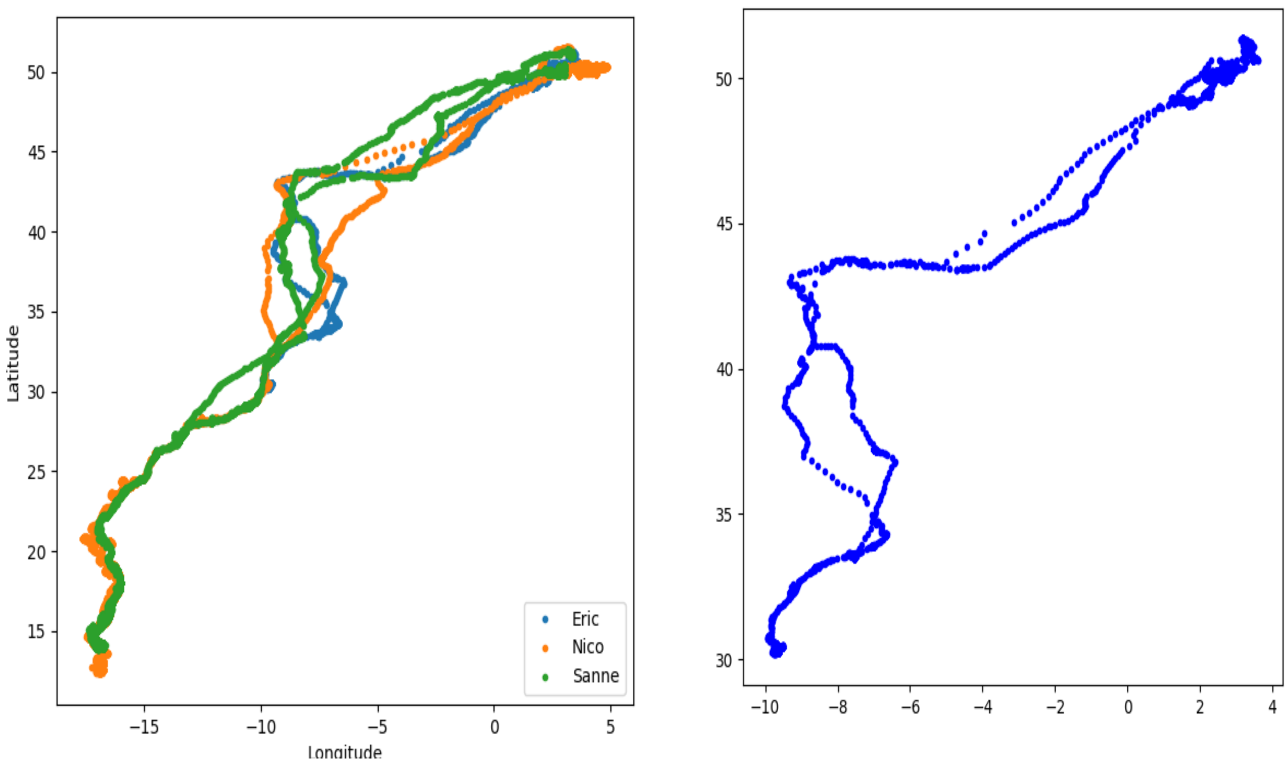

Fig 6.5 Longitude vs Latitude graph

Conclusion

The bird tracking data analysis project has demonstrated the potential of leveraging GPS tracking technology and data visualization techniques to gain deeper insights into bird migration patterns. By plotting the trajectories of multiple birds on a map, we were able to provide a clear visual representation of their migration routes, revealing key migration corridors and stopover points. The daily mean speed analysis highlighted significant variations in the birds' movement patterns over time, indicating periods of high activity and rest. This temporal analysis, combined with the accurate reverse geocoding of countries visited, provided valuable geographical context to the migration data.

The comprehensive visualizations and analyses provided by this project are invaluable for researchers studying bird migration behavior. The identification of key migration corridors and the geographical context of the birds' travels can inform international conservation efforts and policies aimed at protecting migratory bird species. The findings also lay a robust foundation for future research, with potential extensions including the incorporation of more comprehensive datasets, the application of machine learning techniques to predict migration patterns, and the development of more sophisticated interactive visualization tools.

In conclusion, this project has successfully demonstrated the effectiveness of data analysis and visualization in understanding complex biological phenomena like bird migration. The insights gained from this study can contribute significantly to scientific research and conservation efforts, highlighting the importance of advanced technological tools in addressing ecological challenges. By continuing to refine and expand upon this work, we can further enhance our understanding of migratory birds and take more informed actions to ensure their preservation in an ever-changing world.

REFERENCES

[1] R. F. Aunindita, M. Shiam Misbah, S. Bin Joy, M. A. Rahman, S. I. Mahabub and J. Noor Mukta, "Use of Machine Learning and IoT for Monitoring and Tracking of Livestock," 2022 25th International Conference on Computer and Information Technology (ICCIT), Cox's Bazar, Bangladesh, 2022, pp. 815-820, doi: 10.1109/ICCIT57492.2022.10055766.

[2] G. Ramesh, K. Sivaraman, V. Subramani, P. Y. Vignesh and S. V. V. Bhogachari, "Farm Animal Location Tracking System Using Arduino and GPS Module," 2021 International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, India, 2021, pp. 1-4, doi: 10.1109/ICCCI50826.2021.9402610.

[3] Ranjith, S. P. Vijayaragavan, N. V and N. Muthukumaran, "An IoT based Monitoring System to Detect Animal in the Railway Track using Deep Learning Neural Network," 2022 3rd International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India, 2022, pp. 1246- 1253, doi: 10.1109/ICESC54411.2022.9885303.

[4] Ur Rehman et al., "Implementation of an Intelligent Animal Monitoring System Using Wireless Sensor Network and IoT Platform," 2022 International Conference on Cyber Resilience (ICCR), Dubai, United Arab Emirates, 2022, pp. 1-11, doi: 10.1109/ICCR56254.2022.9996080.

[5] Z. Mamatnabiyev, "Animal Tracking System Based on GPS Sensor and LPWAN," 2022 International Conference on Smart Information Systems and Technologies (SIST), Nur-Sultan, Kazakhstan, 2022, pp. 1-4, doi: 10.1109/SIST54437.2022.9945724.

[6] R. L. Junior, "IoT applications for monitoring companion animals: A systematic literature review," 2020 14th International Conference on Innovations in Information Technology (IIT), Al Ain, United Arab Emirates, 2020, pp. 239-246, doi: 10.1109/IIT50501.2020.9299045.

[7] L. Nóbrega, A. Tavares, A. Cardoso and P. Gonçalves, "Animal monitoring based on IoT technologies," 2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany), Tuscany, Italy, 2018, pp. 1- 5, doi: 10.1109/IOT-TUSCANY.2018.8373045.

[8] P. K. Panda, C. S. Kumar, B. S. Vivek, M. Balachandra and S. K. Dargar, "Implementation of a Wild Animal Intrusion Detection Model Based on Internet of Things," 2022 Second International Conference on Artificial Intelligence and Smart Energy (ICAIS), Coimbatore, India, 2022, pp. 1256-1261, doi: 10.1109/ICAIS53314.2022.9742948