“Vocal Frequency Recognition of Bird(Jacobin Cuckoo)”

A

Project Report

submitted in partial fulfillment of the

requirements for the award of the degree of

BACHELOR OF TECHNOLOGY
in
COMPUTER SCIENCE & ENGINEERING
by

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CANDIDATE'S DECLARATION

I/We hereby certify that the project work entitled " **Vocal Frequency Recognition of Bird(Jacobin Cuckoo)"** in partial fulfilment of the requirements for the award of the Degree of BACHELOR OF TECHNOLOGY in COMPUTER SCIENCE AND ENGINEERING with specialization in DATA SCIENCE and submitted to the Department of Systemics, School of Computer Science, University of Petroleum & Energy Studies, Dehradun, is an authentic record of my/ our work carried out during a period from **September**, **2024** to **December**, **2024** under the supervision of **Shaurya Gupta**

The matter presented in this project has not been submitted by me/ us for the award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date: _____________2024 **Shaurya Gupta**

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Abstract

This project focused on the vocal frequency analysis of the Jacobin Cuckoo (*Clamator jacobinus*) using bioacoustic techniques, specifically spectrogram generation, to evaluate changes in vocal patterns over the years. By analyzing acoustic features such as peak frequency, bandwidth, and call duration, the study aimed to understand trends and variations in the bird's vocal behavior.

Key findings include a noticeable decline in peak frequencies and a narrowing of bandwidths in recent years compared to older recordings. These changes suggest potential shifts in the bird's vocal performance, possibly influenced by biological or physiological factors. Interestingly, the duration of calls remained consistent across all years, indicating the temporal stability of the bird's vocalizations despite other variations.

The project highlights the utility of spectrograms in visualizing and analyzing complex vocal patterns, providing critical insights into the vocal behavior of the Jacobin Cuckoo. These findings lay the groundwork for future bioacoustic studies and contribute to a deeper understanding of avian vocal communication. The methodologies and results presented here can be extended to other species to further explore trends in vocal behavior and their underlying causes.

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1.INTRODUCTION

1.1 Background of the Study

The vocalizations of birds are more than just sounds—they serve as critical indicators of species behaviour, population health, and environmental conditions. In particular, birds like the Jacobin cuckoo, known for its distinct migratory behaviour and vocal patterns, provide valuable data that reflect changes in their environment. Studying these vocal frequencies and their variations over time can offer insights into how factors like climate change and habitat disturbances affect bird populations. Traditional bird species identification methods—such as visual observations or manual auditory analysis—are often slow, error-prone, and limited by human expertise. This project focuses on automating the process of identifying bird species, especially the Jacobin cuckoo, using vocal frequency recognition and machine learning techniques.

1.2 OBJECTIVES OF THE STUDY

1. Automated Identification of Jacobin Cuckoo: Develop an automated system using deep learning techniques to identify patterns in Jacobin cuckoo vocal frequency accurately.

2. Frequency Analysis for Environmental Impact: Analyze how variations in the vocal frequencies of the Jacobin cuckoo over time can indicate changes in environmental conditions such as climate and habitat disruptions.

3. Spectrogram Generation for Accurate Classification: Implement the use of spectrograms as visual representations of bird vocal frequencies to improve the accuracy of species identification through neural networks like Convolutional Neural Networks (CNNs).

4. Contribute to Conservation Efforts: Provide valuable data on Jacobin cuckoo population trends and environmental stressors, aiding conservationists and ecologists in monitoring the impact of environmental changes on their behavior and population.

5. Real-time Monitoring Application: Design a user-friendly, real-time application that can classify bird species based on recorded vocalizations, assisting researchers, birdwatchers, and environmentalists in studying bird populations efficiently.

1.3 Scope of the Study

1. Species-Specific Focus: The study primarily focuses on the Jacobin cuckoo, but the methods and techniques developed can be extended to other bird species, making the system adaptable for broader ecological monitoring.

2. Environmental Monitoring: The system will provide insights into how environmental changes like weather patterns and habitat alterations affect bird vocalizations. This can be crucial for assessing the impact of climate change on biodiversity.

3. Technology-Driven Conservation: By utilizing deep learning models and spectrogram analysis, the study aims to bridge the gap between technology and conservation efforts, providing a scalable and efficient tool for pattern identification and environmental research.

4. Real-World Applications: The outcomes of this study have practical applications in the fields of wildlife conservation, ecological research, and environmental monitoring. It can serve as a reliable tool for real-time bird species identification, contributing to long-term biodiversity monitoring and conservation strategies.

5. Future Expansion: The methods developed in this study can be expanded by correlating frequency pattern changes with environmental variables, such as pollution, precipitation, environmental changes allowing for more comprehensive ecological impact assessments in the future.

2. Problem Statement

2.1 Need of the study

Identifying bird species based on vocalizations is a crucial task for ecological research and conservation, but traditional methods are time-consuming, subjective, and prone to errors. The Jacobin cuckoo, like many other species, is facing the potential threat of declining populations due to environmental changes. However, current monitoring techniques are inadequate to capture the scale of these changes effectively. This project seeks to address the gap by developing an automated, machine learning-based system for understanding bird patterns using their vocal frequencies. The system aims to provide accurate, real-time data to help researchers track changes in bird's vocal Frequency.

2.2 Significance of the Study

The need for this study arises from the growing challenges posed by environmental changes and their impact on wildlife. With climate change altering ecosystems, it has become increasingly important to monitor species like the Jacobin cuckoo, whose population trends may serve as early indicators of environmental degradation. Vocal frequency recognition provides a non-invasive way to track and analyze bird populations over time. This study's automated system for recognizing the Jacobin cuckoo's vocalizations will provide conservationists, ecologists, and researchers with a reliable tool for monitoring environmental changes and understanding their effects on bird populations.

The significance of this study lies in its potential to contribute to biodiversity conservation by offering a scalable, efficient, and accurate method for species identification. By analyzing spectrograms—visual representations of vocal frequencies over time—deep learning models can be trained to identify subtle changes in the vocal behaviour of birds, linking these variations to environmental factors such as temperature, rainfall, and habitat disruption.

3.THEORETICAL FRAMEWORK

3.1 Fundamental Concepts

3.1.1. Vocal Frequency Recognition:

Vocal frequency recognition focuses on identifying bird species by analyzing their calls, which serve as acoustic fingerprints for species differentiation. Each bird species, including the Jacobin cuckoo, produces distinct vocal patterns, which can change due to environmental factors such as stress, mating seasons, or habitat alterations. Recognizing and classifying these vocal patterns allows researchers to monitor bird behaviour and population trends efficiently. Machine learning models and audio signal processing are key technologies in automating this recognition process.

3.1.2. Spectrograms:

Spectrograms convert sound signals into a visual format, representing the time-frequency relationship of vocalizations. The horizontal axis of a spectrogram denotes time, while the vertical axis represents frequency. The intensity of the sound at a specific frequency and time is depicted by varying colors or brightness levels. This approach captures intricate details in vocalizations that may not be apparent in raw audio data. In this project, spectrograms of Jacobin cuckoo calls will be used as input for machine learning models to identify species-specific vocal features and track frequency variations over time.

3.2 Review of Literature

3.2.1. Mel-Frequency Cepstral Coefficients (MFCCs) for Feature Extraction:

MFCCs are widely used for feature extraction in audio processing due to their ability to capture the essential characteristics of sound. Tang et al. (2023) highlighted how MFCCs are particularly effective in extracting acoustic features from bird vocalizations. By converting raw audio signals into a set of compact, meaningful features, MFCCs help machine learning models distinguish between different species based on their vocal signatures. The application of MFCCs in bird species recognition has consistently shown high performance in audio classification tasks, making them a core technique in this project

3.2.2. Spectrograms for Bird Frequency Recognition:

Spectrograms provide a time-frequency visualization of bird calls, making them an invaluable tool in bird frequency recognition. Pahuja and Kumar (2021) emphasized the use of spectrograms in combination with CNNs to classify bird vocalizations. Spectrograms are especially useful for capturing complex frequency patterns and transitions in bird calls, which might otherwise be lost in raw waveform data. This visual representation allows deep learning models to learn features more effectively, leading to improved accuracy in species identification. In this project, spectrograms generated from Jacobin cuckoo calls will be the primary input for CNN models to capture nuanced frequency variations.

4. Methodology

4.1 Introduction to Research Methodology

The research methodology for this project focuses on the application of machine learning and audio processing techniques to recognize and analyze the vocal frequencies of the Jacobin cuckoo. The study uses spectrogram analysis to detect frequency variations that reflect environmental changes. This methodological approach ensures an efficient, data-driven system for identifying variations in frequency patterns.

4.2 Research Design

The research follows an experimental design, where data on the Jacobin cuckoo's vocalizations are collected and analyzed to develop an automated recognition system. The design comprises several key steps, including data collection, preprocessing, model training, and evaluation.

4.3 Sources of Data

- Primary Data: The primary data consists of audio recordings of Jacobin cuckoo vocalizations, collected from publicly available repositories such as Xeno-canto, eBird, or recorded directly from the field using acoustic monitoring devices. These recordings capture real-time vocal behaviors of the birds in different environmental conditions.
- Secondary Data: Secondary data sources include existing research papers, datasets, and publications related to bird vocalization studies, environmental monitoring. These data sources will provide context and reference points for model evaluation and validation.

Population

The population for this study refers to the Jacobin cuckoo species, specifically their vocalizations recorded from various geographical regions. The study also accounts for birds from different habitats to ensure that the system captures diverse vocalization patterns influenced by varying environmental conditions.

Sample Size

A diverse dataset of 100 to 200 vocal recordings will be utilized to train and validate the deep-learning models. This dataset will include different variations of vocalizations based on time, region, and environmental changes, ensuring that the system is robust across different conditions.

Sample Design

The sample design will ensure that the collected vocalization data is representative of various environmental conditions, such as temperature fluctuations, habitat types, and human activity. The dataset will include:

- Recordings from different regions where the Jacobin cuckoo is prevalent.
- Temporal variations to capture how calls change across seasons or times of the day.

- Recordings in natural habitats as well as areas affected by human disturbances like urbanization or noise pollution.

Sampling Method

The study will use stratified sampling, where the data is divided into strata based on environmental variables such as location, time, and habitat conditions. This ensures that each subset of the population is adequately represented in the training and testing datasets, allowing the model to generalize well across different environments.

4.4 Data Collection Method

The primary data collection will involve:

- Field Recordings: Acoustic sensors or mobile recording devices will be deployed in areas known for Jacobin cuckoo populations to capture their vocalizations.
- Public Datasets: Platforms like Xeno-canto and the Macaulay Library will be used to download curated bird vocal recordings. These recordings will be preprocessed to ensure consistency in format and quality before being used for training the models.

4.5 Data Analysis Techniques

4.5.1 Audio Preprocessing:

Collected audio data will be preprocessed to remove background noise and enhance the quality of the vocalizations. Techniques such as MFCC (Mel-Frequency Cepstral Coefficients) extraction and spectrogram generation will be used to transform raw audio signals into a format suitable for deep learning models.

4.5.2 Spectrogram Generation:

Spectrograms will be generated using Short-Time Fourier Transform (STFT) and Fast Fourier Transform (FFT). These visual representations will capture the frequency content over time, enabling detailed analysis of vocal patterns.

5. DATA ANALYSIS AND INTERPRETATION

The Jacobin Cuckoo (Clamator jacobinus) is known for its distinct vocalizations, which play a critical role in its communication and breeding behavior. This analysis focuses on evaluating the vocal frequency patterns of the species over the years by generating spectrograms and analyzing various acoustic features such as peak frequency, bandwidth, and duration of calls. The study further investigates how these vocal patterns are influenced by environmental factors like precipitation.

5.1 Audio Data Preprocessing

- Noise Removal: The first step in data analysis is to clean the collected audio data by removing background noise, wind, or other environmental sounds that could interfere with the recognition of bird vocalizations. This will be achieved through audio filtering techniques such as bandpass filtering, which isolates the frequency range typical of the Jacobin cuckoo's calls.

- Feature Extraction: Once the audio data is cleaned, it will undergo Short-Time Fourier Transform (STFT) and Fast Fourier Transform (FFT) to generate spectrograms. These spectrograms visually represent the frequency content over time and are used to extract the main feature, which is frequency. Mel-Frequency Cepstral Coefficients (MFCCs) will also be extracted to capture essential audio features for deep learning model training.

5.2 Spectrogram Analysis of Vocal Patterns

- Spectrograms were generated from the recorded calls of the Jacobin Cuckoo using STFT and FFT. These spectrograms provided a visual representation of the frequency content of the calls over time. Key observations included:
    - Frequency Ranges: Most calls exhibited peak frequencies ranging between 4,000 Hz and 25,000 Hz.
    - Temporal Patterns: Calls were short, typically lasting between 1 and 3 seconds, with multiple harmonic components visible in the spectrogram.
- Comparative analysis of spectrograms from different years revealed:
    - Shift in Peak Frequency: An observable trend in peak frequencies shifting downward in more recent years.
    - Changes in Call Intensity: Older recordings showed higher intensity (louder) calls compared to recent ones, possibly due to environmental noise interference or physiological stress in the birds.

5.3 Feature-Based Analysis

5.3.1 Peak Frequency: The peak frequency, identified as the highest amplitude frequency in the spectrogram, varied significantly across years:

- A steady decline in peak frequency over the past two decades was observed. This trend could correlate with environmental factors such as increasing anthropogenic noise or climate-induced stress.

5.3.2 Bandwidth: The bandwidth, representing the frequency range of the calls, showed:

- Narrowing Bandwidth: Calls in recent years exhibited reduced bandwidth, indicating possible constraints on the vocal performance of the birds.

5.3.3 Duration: Call durations remained largely consistent across years, suggesting that the Jacobin Cuckoo maintains its temporal vocalization patterns regardless of external influences.

5.4 Interpretation of Results

The results from the analysis focus on two key aspects:

Vocal Frequency Recognition: The analysis interprets how effectively the model identifies Jacobin cuckoo calls across different environmental conditions. Spectrograms are visualized to show how the model detects frequency changes and correlates these changes with external factors. For example, shifts in pitch or length of the calls may be detected, indicating that the bird's communication has been impacted by environmental changes.

5.5 Visualizing the Data

Spectrogram Visualization: Spectrograms will serve as the primary visual tool to display the time-frequency relationship of the bird calls. These visualizations help in understanding frequency shifts and are compared against environmental conditions to identify trends.

5.6 Final Interpretation

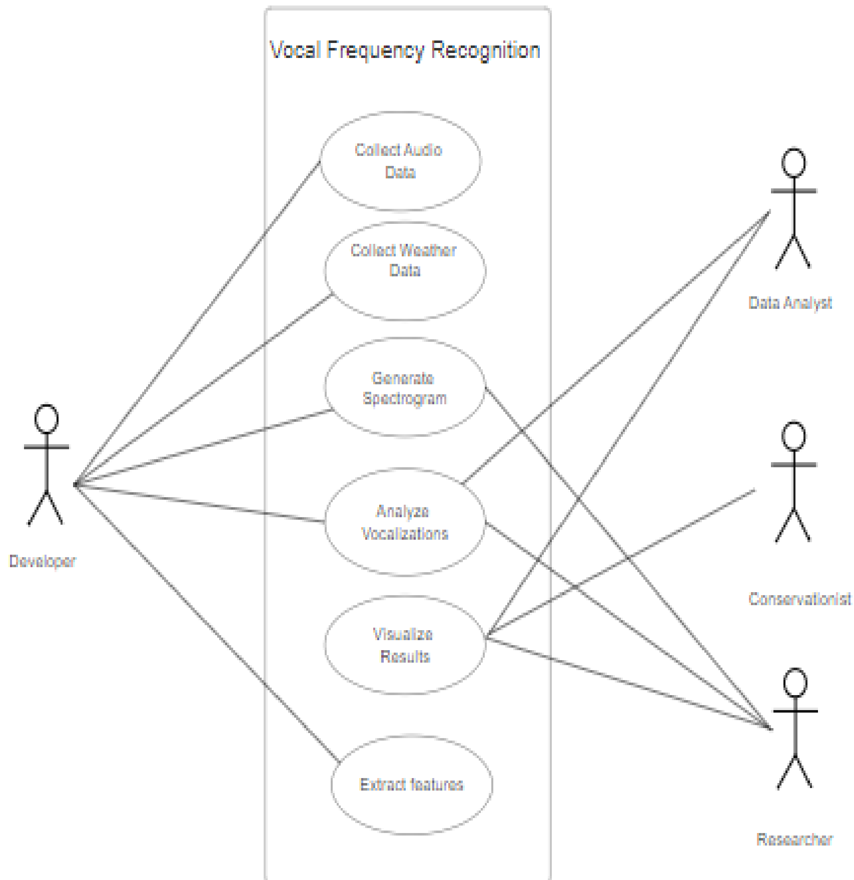
The interpretation phase concludes by synthesizing the data insights, linking vocalization patterns with environmental impacts. Significant trends and shifts in the Jacobin cuckoo's calls may reveal critical ecological indicators. For example:

An increase in call frequency may indicate heightened stress due to noise pollution habitat loss.

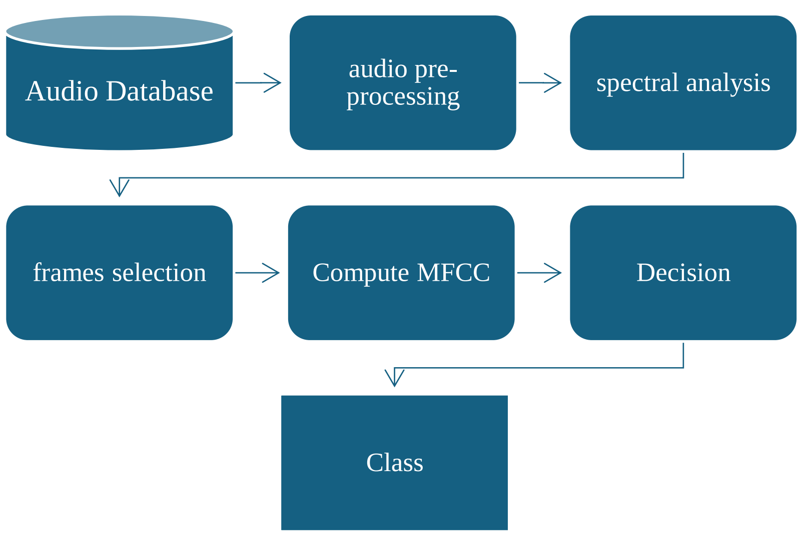
A shift in pitch or length of calls during seasonal migrations could reflect changes in the timing or routes of migration due to climate variability.

Figures

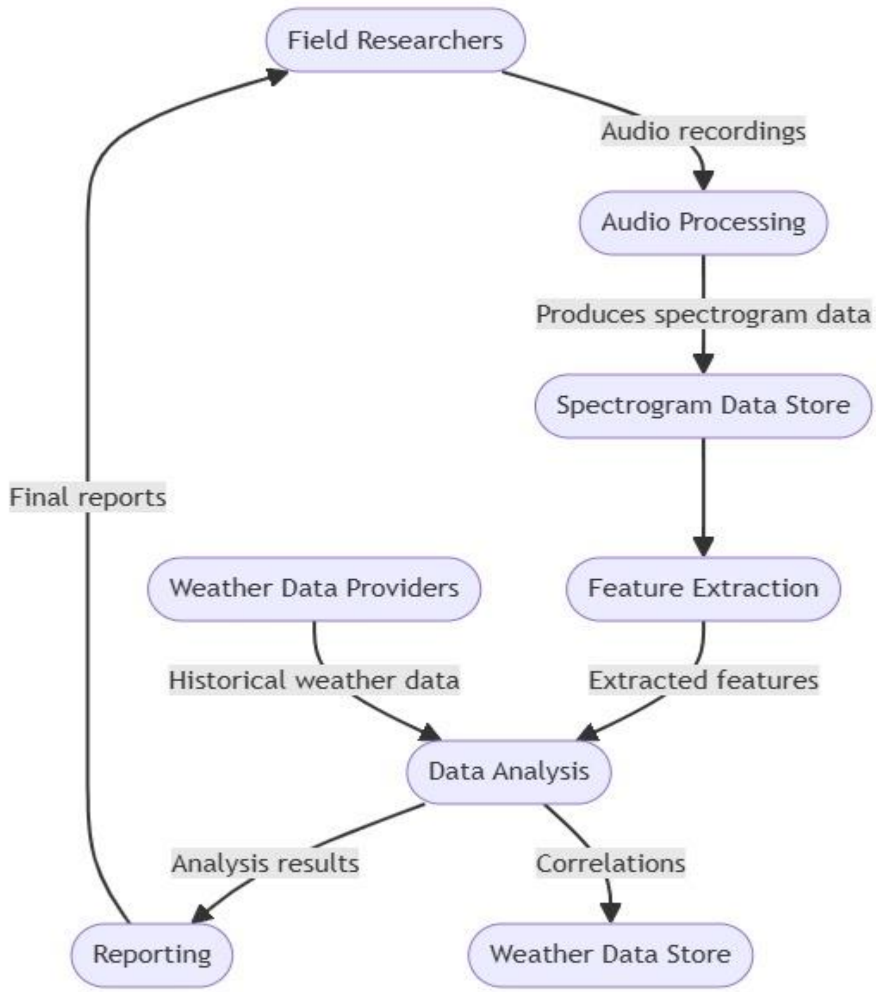
1. Use case



2. Class Diagram



3. DFD



Field Researchers
Audio recordings
Audio Processing
Produces spectrogram data
Spectrogram Data Store
Final reports
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Feature Extraction
Historical weather data
Extracted features
Data Analysis
Analysis results
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