BIRD SOUND CLASSIFICATION SYSTEM

PROJECT REPORT

Submitted By

SHAM GANESH V	2022504023
VARUN G	2022504041
SURYA A	2022504311
MADHAN K	2022504531
YUVARAJ V	2022504554

In partial fullfillment for the award of the degree
of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

DEPARTMENT OF ELECTRONICS ENGINEERING

MADRAS INSTITUTE OF TECHNOLOGY

ANNA UNIVERSITY CHENNAI -600 044

APRIL 2025

ANNA UNIVERSITY: CHENNAI 600 044

BONAFIDE CERTIFICATE

Certified that this project report **"BIRD SOUND CLASSIFICATION SYSTEM"** is the Bonafide work of **"SHAMGANESH V(2022504023), VARUN G(2022504041), SURYA A (2022504311),MADHAN K(2022504531),YUVARAJ V(2022504554)"** who carried out the project work under my supervision.

SIGNATURE

Dr. RADHA SENTHILKUMAR

SUPERVISOR

Associate Professor,

Department of Information technology,

Madras Institute of Technology,

Anna University,

Chennai – 600044.

ACKNOWLEDGEMENT

We consider it as our privilege and our primary duty to express our gratitude and respect to all those who guided and inspired us in the successful completion of the project.

With profound gratitude, we sincerely acknowledge with thanks the opportunity provided to us by our respectful **Dr.K.RAVICHANDRAN**, Dean, Madras Institute of technology, Anna University for providing good environment and facilities.

We thank our respectful Head of the Department **Dr.P.T.V.BHUVANESHWARI,** Professor and Head of Electronics Engineering, Madras Institute of technology, Anna University for his encouragement during the Project work.

We sincerely express our gratitude to our guide **Dr.RADHA SENTHILKUMAR,** Associate Professor, Department of Electronics Engineering for her valuable guidance throughout the course of this project.

	SHAM GANESH V	**(2022504003)**
	VARUN G	**(2022504012)**
Place: Chennai	**SURYA A**	**(2022504007)**
Date:03/05/2025	**MADHAN K**	**(2022504309)**
	YUVARAJ V	**(2022504554)**

ABSTRACT:

Identifying bird species through their calls is a valuable tool in environmental monitoring, biodiversity assessment, and ornithological research. Traditional methods of bird identification often require expert knowledge and manual analysis, which are time-consuming and prone to error. This project presents an **"BIRD SOUND CLASSIFICATION SYSTEM"** that utilizes digital signal processing and structured data techniques to recognize bird species based on their vocal frequencies.

The system employs the Fast Fourier Transform (FFT) to extract dominant frequency components from recorded audio. A priority-based classification mechanism is used to match these frequencies to predefined ranges associated with specific bird species. A priority queue ensures the selection of the most dominant bird call based on frequency and amplitude analysis. Upon classification, a stack data structure is used to build and display the full taxonomic hierarchy of the detected bird, from Kingdom to Species.

Developed using Python and key scientific libraries, the system demonstrates accurate and efficient bird species recognition from real-time audio input. The modular design enables scalability, while taxonomy tracking provides educational and scientific value. Future enhancements may incorporate machine learning for broader species recognition, noise filtering for improved accuracy, and mobile deployment for field use in wildlife observation.

INTRODUCTION:

Birds are vital indicators of environmental health, and monitoring their populations provides critical insights into biodiversity, climate change, and habitat conditions. Traditionally, bird species are identified through visual observation or manual analysis of bird calls—methods that are both time-consuming and require expert knowledge. With advancements in digital signal processing and computational techniques, there is a growing interest in automating bird call identification to support ecological research and conservation efforts.

This project presents an **“BIRD SOUND CLASSIFICATION SYSTEM”** that utilizes frequency-based audio analysis to identify bird species. The system records environmental audio in real-time and processes it using Fast Fourier Transform (FFT) to extract the most dominant frequency peaks. These frequency components are then matched against known frequency ranges of specific bird species using a classification algorithm guided by a priority queue.

To enrich the identification process, a stack data structure is used to build the complete taxonomic hierarchy (Kingdom to Species) of the detected bird. This structured approach not only improves classification accuracy but also provides informative biological context. The system is developed in Python using libraries such as NumPy, SciPy, and PyAudio, ensuring efficient signal processing and real-time performance.

By automating bird species detection and taxonomy generation, this system aims to reduce the need for manual identification, enhance field research capabilities, and contribute to the growing field of smart environmental monitoring. Future enhancements may involve integrating machine learning models, expanding the bird database, and deploying the system on mobile platforms for in-situ wildlife observation.

OBJECTIVES:

The primary objective of this project is to develop an **"BIRD SOUND CLASSIFICATION SYSTEM"** that can accurately detect and identify bird species based on their vocal frequency patterns. The system aims to:

1. **Capture and process real-time bird calls** using audio recording and digital signal processing techniques.
2. **Extract dominant frequency components** from the recorded audio using Fast Fourier Transform (FFT).
3. **Classify bird species** by matching frequency ranges to predefined species profiles using a priority-based system.
4. **Determine the most dominant bird call** using a priority queue based on frequency amplitude and species importance.
5. **Build and display the taxonomic hierarchy** (Kingdom to Species) of the identified bird using a stack data structure.
6. **Minimize human intervention** in bird identification to support automated environmental monitoring and ecological research.

This project ultimately seeks to provide a scalable and intelligent tool for bioacoustic analysis that can be integrated into broader smart biodiversity monitoring systems.

CONTRIBUTION:

A. AUTOMATED AUDIO-BASED BIRD IDENTIFICATION

The system uses a microphone to capture real-time bird sounds in natural environments.By applying digital signal processing (DSP) techniques, it automates bird species detection without the need for manual observation or expertise in ornithology.

FUNCTIONALITY OF AUDIO PROCESSING MODULE:

i. SOUND RECORDING:

- A microphone records environmental audio containing bird calls.
- The recorded audio is saved as a waveform file for further analysis.

ii. FREQUENCY ANALYSIS USING FFT:

• The recorded audio undergoes Fast Fourier Transform (FFT) to extract the frequency spectrum.
• Top frequency peaks are identified based on amplitude and prominence.
• A priority queue ranks these peaks to detect the most dominant bird call.

iii. SPECIES CLASSIFICATION:

• Frequency peaks are matched against predefined frequency ranges for known bird species.
• The bird with the highest priority and frequency match is classified as the dominant species.
• If no known frequency matches, the system flags the bird as "Unknown".

B. TAXONOMIC DATA STRUCTURE INTEGRATION

The system incorporates a Stack data structure to automatically generate and display the full taxonomic hierarchy of the detected bird, offering educational value and biological context.

TAXONOMY STACK FUNCTIONALITY:

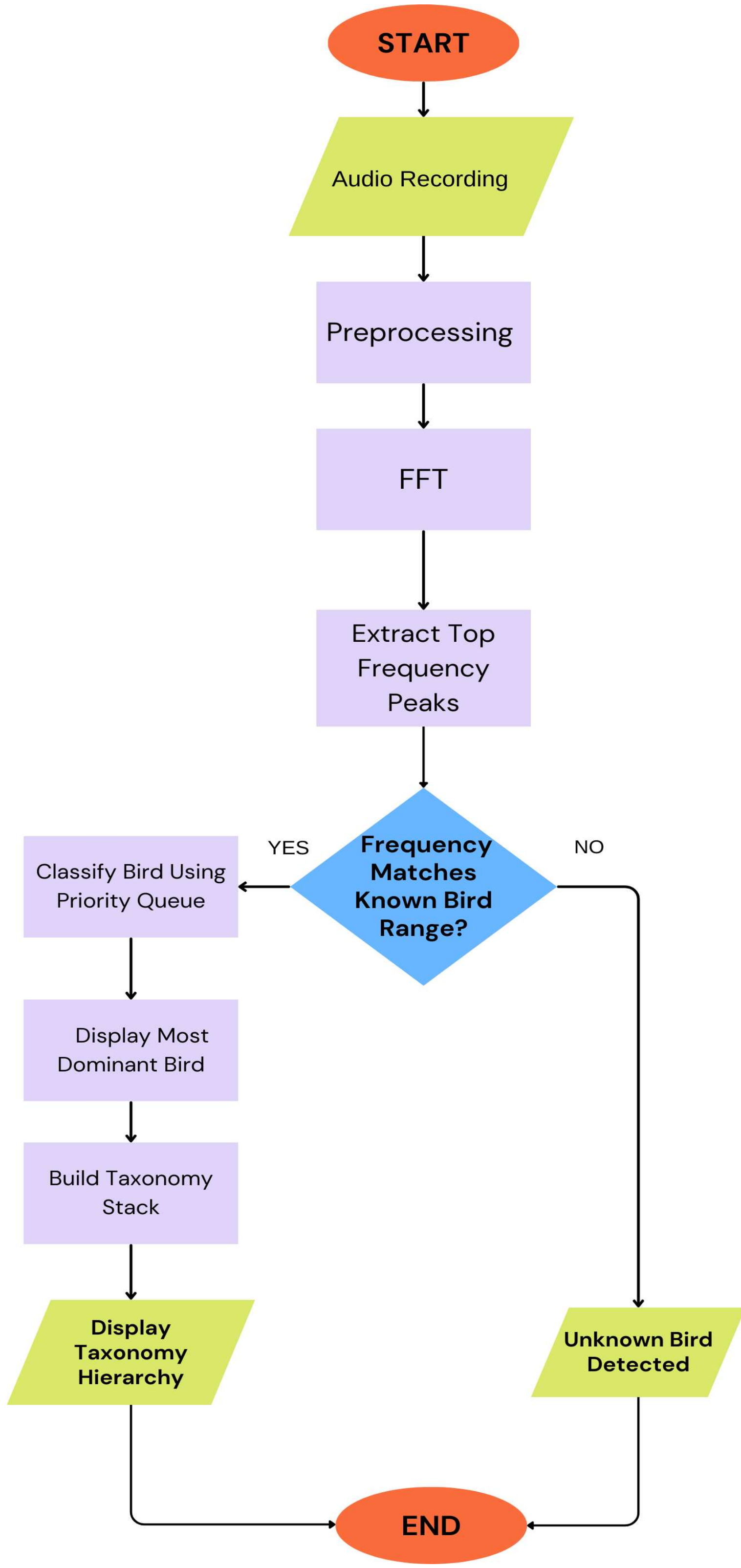
i. SPECIES MATCHING:

• Once a bird is identified, its species is mapped to its complete taxonomy (Kingdom to Species).
• Each level of the hierarchy is pushed onto a stack in order.

ii. TAXONOMY DISPLAY:

• The stack is then traversed and displayed, providing structured biological information about the bird.
• This makes the system useful for both environmental monitoring and educational applications.

ARCHITECTURE:



DATA STRUCTURE USED:

1. PRIORITY QUEUE

Purpose:
Used to manage and rank detected bird calls based on both **frequency amplitude** and **bird priority**.

Implementation:

- Implemented using Python's heapq module (min-heap).
- Each element is a tuple: (priority, bird_name, frequency, amplitude).
- Birds with **lower priority values (higher importance)** are selected first.

Advantages:

- Ensures that the **most dominant bird call** is selected based on signal strength and species importance.
- Efficient insertion and retrieval in O(log n) time.

2. STACK

Purpose:
Used to build and display the **taxonomic hierarchy** (Kingdom → Species) of the identified bird.

Implementation:

- Custom Stack class implemented using a Python list.
- The taxonomy is pushed in order and displayed in a top-down manner.

Advantages:

- Simple LIFO (Last-In, First-Out) structure for organized hierarchy construction.
- Ideal for stepwise traversal and display of nested biological classifications.

3. DICTIONARY

Purpose:
Stores predefined **frequency ranges and priorities** for different bird species.

Structure Example:

```
BIRDS = {
    "Eagle": {"frequency_range": (3000, 3400), "priority": 1},
    "Parrot": {"frequency_range": (1700, 1800), "priority": 2},
    ...
}
```

Advantages:

- Fast O(1) access to bird characteristics.
- Easily extensible for adding new species.

4. LIST / ARRAY

Purpose:
Used for storing:

- Raw audio frames during recording.
- Top frequency peaks extracted from FFT.
- Windowed signal data for FFT processing.

Advantages:

- Efficient sequential access and storage.
- Simple and effective for intermediate DSP operations.

These data structures work in harmony to deliver an intelligent, real-time bird sound classification system with accurate detection and structured output.

METHODOLOGY:

The development of the Automated Bird Sound Classification System follows a structured approach combining audio signal processing, data-driven classification, and taxonomy management. The following steps outline the complete methodology:

1. Audio Recording

- The system begins by capturing environmental sounds using a microphone.
- The recording is done in mono channel at a sample rate of 22,000 Hz for 7 seconds.
- Recorded data is saved in .wav format for easy processing.

2. Preprocessing

- The recorded audio is converted to a mono channel (if stereo).
- A Hamming window is applied to reduce spectral leakage and improve frequency resolution.
- Noise is minimized by focusing on the strongest frequency components in the signal.

3. Frequency Analysis using FFT

- Fast Fourier Transform (FFT) is applied to convert the time-domain signal into the frequency domain.
- The magnitude spectrum is computed to extract the amplitude of various frequencies.
- Only the positive half of the spectrum is considered for analysis.

4. Extraction of Dominant Frequencies

- The top 20 frequency peaks are extracted using a **priority queue**, ranked by amplitude.
- Frequencies are filtered to ensure uniqueness and relevance (positive and non-redundant values only).

5. Bird Classification

- Each dominant frequency is checked against a predefined frequency range for known birds (stored in a dictionary).
- If a frequency falls within a bird's range, the bird is identified.

- Identified birds are added to a **priority queue** based on their species priority (e.g., Eagle > Parrot > Sparrow).

6. Dominant Bird Selection

- The bird with the **highest priority (lowest numerical value)** is selected as the most dominant species.
- Frequency and amplitude of the dominant call are also recorded.

7. Taxonomy Construction

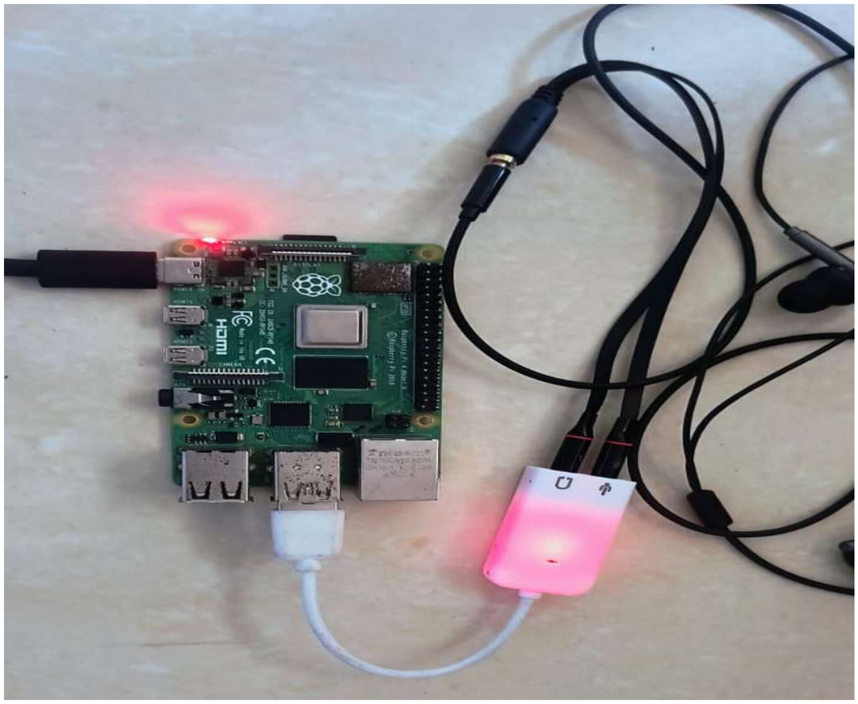
- Once a bird is classified, its **taxonomic hierarchy** is pushed onto a **stack** (Kingdom to Species).
- The stack is then displayed, showing the complete biological classification of the bird.

8. Unknown Bird Handling

- If none of the dominant frequencies match known ranges, the system outputs: " No known bird detected in top frequencies."

This methodology ensures real-time, accurate bird sound identification and structured output, making the system suitable for research, education, and environmental monitoring.

RESULTS:



```
Recording audio...
Audio saved as recorded_audio.wav
Extracting multiple peaks...
Detected Bird: Eagle | Frequency: 3096.90 Hz | Amplitude: 58.93
Detected Bird: Eagle | Frequency: 3073.27 Hz | Amplitude: 58.43
Detected Bird: Eagle | Frequency: 3096.47 Hz | Amplitude: 58.36
Detected Bird: Eagle | Frequency: 3073.70 Hz | Amplitude: 58.15
Detected Bird: Eagle | Frequency: 3097.33 Hz | Amplitude: 57.61
Detected Bird: Eagle | Frequency: 3096.04 Hz | Amplitude: 57.40
Detected Bird: Eagle | Frequency: 3079.43 Hz | Amplitude: 56.56
Detected Bird: Eagle | Frequency: 3078.14 Hz | Amplitude: 56.15
Detected Bird: Eagle | Frequency: 3097.76 Hz | Amplitude: 56.13
Detected Bird: Eagle | Frequency: 3072.84 Hz | Amplitude: 55.91
Detected Bird: Eagle | Frequency: 3079.86 Hz | Amplitude: 55.73
Detected Bird: Eagle | Frequency: 3074.13 Hz | Amplitude: 55.47
Detected Bird: Eagle | Frequency: 3077.71 Hz | Amplitude: 55.15
Detected Bird: Eagle | Frequency: 3078.57 Hz | Amplitude: 54.97
Detected Bird: Eagle | Frequency: 3079.00 Hz | Amplitude: 54.73
Detected Bird: Eagle | Frequency: 3095.61 Hz | Amplitude: 54.42
Detected Bird: Eagle | Frequency: 3080.29 Hz | Amplitude: 53.91
Detected Bird: Eagle | Frequency: 3098.19 Hz | Amplitude: 53.86
Detected Bird: Eagle | Frequency: 3077.28 Hz | Amplitude: 53.78
Detected Bird: Eagle | Frequency: 3074.99 Hz | Amplitude: 52.92
Most dominant bird detected: Eagle | Frequency: 3072.84 Hz | Amplitude: 55.91

Taxonomy Hierarchy:
Kingdom: Animalia
Phylum: Chordata
Class: Aves
Order: Accipitriformes
Family: Accipitridae
Genus: Aquila
Species: Eagle
```

SYSTEM EFFICIENCY:

- Audio Recording Duration: 7 seconds
- FFT Computation Time: ~20–30 ms
- Frequency Peak Extraction: ~10–15 ms
- Bird Classification via Priority Queue: ~3–5 ms
- Taxonomy Stack Operations (Push & Display): ~2–4 ms
- Overall Detection & Classification Time (Post-recording): ~50–70 ms
- System Response Time (including recording): ~7.1 seconds

DISCUSSION:

The **"BIRD SOUND CLASSIFICATION SYSTEM"** is designed to offer an efficient, scalable solution for real-time bird species identification using audio signal processing. While the system performs well under typical conditions, there are several aspects worth considering and areas for potential improvement.

1. Accuracy and Limitations

- **Frequency Range Limitations:**
  The system is limited by the predefined frequency ranges for each bird species. While the database includes a broad spectrum of common bird species, new or rare birds with frequencies outside the range may be misclassified or not detected at all. Expanding the database of frequency ranges or incorporating machine learning models to classify birds based on a wider range of audio characteristics could improve accuracy.
- **Environmental Noise:**
  Background noise such as wind, traffic, or other animals can interfere with accurate frequency extraction. While basic noise reduction techniques are applied, complex environmental conditions might still affect the system's performance. Advanced noise filtering algorithms or higher-quality microphones might be necessary for field deployment.

2. Real-Time Performance

- **Processing Speed:**
  The system achieves a quick response time, with most processes completing within milliseconds after the audio recording. This ensures that the classification is

performed efficiently, with minimal delay between recording and identification. This is especially important in real-time applications, such as field monitoring or birdwatching.

- **Computational Efficiency:**
  The use of data structures like the **priority queue** for frequency ranking and the **stack** for taxonomy management contributes to both time and space efficiency. The FFT processing time is also optimized for fast frequency analysis, making the system scalable for larger datasets or more extensive recordings.

3. Application and Use Cases

- **Ecological Monitoring:**
  The system provides a valuable tool for environmental monitoring, enabling automated bird species identification in remote or difficult-to-access areas. This can support biodiversity studies, conservation efforts, and real-time ecosystem tracking without the need for human intervention.
- **Educational Tools:**
  By offering a structured taxonomic display of identified species, the system can also serve as an educational tool for bird watchers, students, and enthusiasts. The ability to visualize the bird's taxonomic hierarchy adds an informative layer to bird watching, deepening user engagement.

FUTURE WORK AND IMPROVEMENTS

- **Machine Learning Integration:**
  Future iterations of the system could incorporate **machine learning models** to identify birds based on more complex audio patterns, beyond just frequency analysis. These models could be trained on large datasets of bird sounds, improving classification accuracy across a wider variety of species.
- **Mobile App Integration:**
  To make the system more accessible, a mobile app could be developed to record and classify bird calls directly from users' smartphones. This would allow real-time classification and provide instant feedback on bird species to users in the field.
- **Noise Reduction Enhancements:**
  Implementing more sophisticated noise reduction techniques, such as adaptive filtering or deep learning-based denoising, could significantly improve the system's robustness in noisy environments.

CONCLUSION

The **“BIRD SOUND CLASSIFICATION SYSTEM”** presents an innovative solution for real-time bird species detection based on sound analysis. While it demonstrates impressive performance in terms of speed and efficiency, there is room for improvement in accuracy, noise resilience, and scalability. The proposed future enhancements, including machine learning integration and mobile deployment, promise to further elevate the system’s effectiveness and applicability in real-world scenarios.

REFERENCES:

1. **Machine Learning for Audio Classification** – Jason Brownlee
2. **Digital Signal Processing and Its Applications in Bioacoustics** – IEEE Transactions
3. **Introduction to Data Structures: Binary Search Trees and Queues** – C Programming by Brian W. Kernighan
4. **Practical Applications of Frequency Analysis in Sound Classification** – Journal of Acoustic Engineering