# Project Base Learning
**(PBL)**

# Birdcall Recognition: EDA and Audio FE

**Software Requirement Specification for a deep learning model to identify birth species and population estimation according to places.**

**Submitted By:**
**Harsh - Goyal**
**Reg. No.: 219311227**
**&**
**Abhishek – Soni**
**Reg. No: 219310067**

**Proposed By:**
**Dr. Deepak Panwar**

**DEPARTMENT OF COMPUTER SCIENCE ENGINEERING**
**MANIPAL UNIVERSITY JAIPUR**
**JAIPUR-303007, RAJASTHAN, INDIA**

**August - November**
**2023**

# Table of Contents

# 1. Introduction

## 1.1 Purpose

The purpose of the Bird Call Recognition project is to develop a sophisticated and accurate system capable of automatically identifying and classifying bird species based on their distinct vocalizations or calls. This system aims to contribute to ornithological research, environmental monitoring, and wildlife conservation efforts by providing a tool for the automated and efficient tracking of bird populations and behaviors in various natural habitats.

This project seeks to address the following objectives:

Objective 1: Create a robust and scalable platform for collecting, storing, and analyzing bird audio recordings.
Objective 2: Implement state-of-the-art machine learning and signal processing techniques to extract meaningful features from bird calls.
Objective 3: Train and fine-tune machine learning models to accurately classify bird species from audio data.
Objective 4: Provide an intuitive and user-friendly interface for researchers, wildlife enthusiasts, and conservationists to interact with the system.
Objective 5: Contribute to scientific knowledge about avian biodiversity, migration patterns, and ecological health.
By achieving these objectives, the Bird Call Recognition project aims to facilitate bird species identification, data collection, and analysis, ultimately aiding in the understanding and preservation of avian ecosystems.

This purpose statement gives a clear overview of why the project is being undertaken and what goals it aims to achieve. It provides context for the subsequent sections of the SRS, which will delve into the technical details, requirements, and specifications of the system..

## 1.2 Document Conventions

In this SRS document for the Bird Call Recognition project, the following conventions will be used for clarity and consistency:

Bird Call Recognition System: Refers to the software system developed for identifying bird species based on audio recordings.
User: Represents any individual interacting with the Bird Call Recognition System, including researchers, ornithologists, and system administrators.
Audio Data: Denotes recorded bird vocalizations or calls, which serve as the primary input to the system.
Machine Learning Model (ML Model): Represents the algorithms and models used for species classification.
GUI: Stands for "Graphical User Interface" and refers to the visual interface through which users interact with the system.
Formatting:

Headings and Subheadings: Headings will use a consistent numbering scheme (e.g., 1. Introduction, 1.1 Purpose, 2. System Overview) to organize sections.
Bold Text: Key terms, section headings, and subheadings will be in bold for emphasis and easy identification. References:

Citations: All external references, such as research papers, standards, or APIs, will be cited using a standardized format (e.g., APA, IEEE) as applicable.
Hyperlinks: Relevant web links may be provided within the document for easy access to external resources.
Lists and Enumerations:

Bullet Points: Bullet points will be used for listing items within a section when a sequential order is not required.
Numbered Lists: Numbered lists will be used for items that need to be presented in a specific order or sequence. Notations:

Variables and Code: Code snippets, variable names, and code-related content will be presented using a monospaced font for clear distinction from regular text. Acronyms and Abbreviations:

Acronyms: Acronyms and abbreviations will be spelled out in their first occurrence, followed by the acronym or abbreviation in parentheses (e.g., Machine Learning Model (ML Model)). Figures and Tables: Figures: Figures will be labeled and numbered sequentially (e.g., Figure 1, Figure 2) with descriptive captions.

Tables: Tables will be labeled and numbered sequentially (e.g., Table 1, Table 2) with clear column headers and row labels.
These document conventions will help maintain consistency and clarity throughout your SRS document, making it easier for readers to understand and navigate the content. Adjust these conventions as needed to suit the specific needs of your project and the preferences of your team.

## 1.3 Intended Audience and Reading Suggestions

Certainly! Identifying the intended audience and providing reading suggestions in your Software Requirements Specification (SRS) document is essential to ensure that the document is accessible and useful to the people who will be involved in the project. Here's a sample section on intended audience and reading suggestions for our Bird Call Recognition project's SRS:

This section outlines the intended audience for this Software Requirements Specification (SRS) document. The document is designed to be informative and valuable to the following groups and individuals:

1) Development Team: The project's development team, including software engineers, data scientists, and machine learning experts, will use this document as a comprehensive reference to understand the project's requirements and technical specifications.

2) Project Stakeholders: Project stakeholders, including project managers, sponsors, and investors, will gain insights into the project's scope, objectives, and technical details to ensure alignment with business goals and resource allocation.

3) Subject Matter Experts (Ornithologists): Ornithologists and bird experts who are collaborating on the project or providing domain-specific knowledge will find this document useful to understand the technical aspects of the Bird Call Recognition System.

4) Quality Assurance and Testing Teams: QA and testing teams will refer to this document to create test plans and test cases, ensuring that the system meets the specified requirements and functions correctly.

5) User Interface Designers: Designers responsible for creating the system's graphical user interface (GUI) will use this document to understand user interaction requirements.

6) End Users: While not the primary audience, end users, such as researchers and wildlife enthusiasts, may find value in understanding the system's capabilities and limitations.

7) Future Developers and Maintainers: Individuals who may work on future enhancements or maintenance of the system will rely on this document to comprehend the system's architecture and requirements.

Reading Suggestions::

To gain a deeper understanding of the project's context, technology, and domain-specific knowledge, the following reading suggestions are recommended:

1)Introduction to Ornithology - A foundational resource for those new to ornithology, providing insights into bird biology, behavior, and vocalizations.

2)Machine Learning and Deep Learning Tutorials - TensorFlow's official tutorials offer a comprehensive introduction to machine learning and deep learning techniques, which are fundamental to this project.

3)Python Documentation - As Python is a primary programming language for this project, a good understanding of Python fundamentals is essential.

4)Librosa Documentation - Librosa is a popular Python library for audio analysis, and its documentation can help with audio feature extraction.

5)User Interface (UI) Design Principles - For those involved in GUI design, understanding UI design principles is valuable.

6)Project Management and Software Development- For project managers and stakeholders, resources from the Project Management Institute (PMI) can provide insights into effective project management and software development processes.

These reading suggestions will help various stakeholders, from developers to ornithologists, gain the necessary background knowledge to contribute effectively to the Bird Call Recognition project.

## 1.4 Product Scope

Project Goals

This section articulates the primary goals and objectives of the Bird Call Recognition project. These goals serve as the driving force behind the development effort and guide the team in delivering a successful system.

1.4.1 Overall Project Goals

Goal 1: Develop a Robust Bird Call Recognition System

Objective: Create a reliable and accurate system capable of recognizing and classifying bird species based on their unique vocalizations, contributing to the field of ornithology and wildlife conservation.
Goal 2: Enhance Research and Conservation Efforts

Objective: Provide a valuable tool for researchers, ornithologists, and conservationists to monitor bird populations, behaviors, and biodiversity more efficiently and comprehensively. Goal 3: Foster Environmental Awareness

Objective: Promote awareness and appreciation of avian ecosystems among the general public, encouraging participation in bird-related citizen science projects.

1.4.2 Business Goals

This section outlines the key business goals associated with the Bird Call Recognition project. These goals focus on the broader organizational objectives and benefits that the project aims to achieve.

Business Goal 1: Advance Ornithological Research

Objective: Facilitate and accelerate scientific research on bird species, their behaviors, and ecological interactions through the provision of a powerful bird call recognition tool.
Key Result: Increase the quantity and quality of research publications and discoveries related to avian biodiversity.

Business Goal 2: Support Wildlife Conservation

Objective: Assist wildlife conservation organizations and agencies in monitoring bird populations and habitats, aiding in the preservation of threatened and endangered species.
Key Result: Contribute to conservation efforts by providing valuable data and insights into bird populations and habitats.

These business goals align the Bird Call Recognition project with strategic objectives related to research, conservation, public engagement, and sustainability. They demonstrate the project's potential to create value for both the scientific community and broader society while ensuring responsible data usage and ethical practices. Customize these goals to match the specific priorities and mission of your organization or project stakeholders.

## 1.5 References

Software Requirement Specification document BirdCLEF @2021

https://www.kaggle.com/code/andradaolteanu/birdcall-recognition-eda-and-audio-fe/notebook
https://www.google.co.in/
https://www.wikipedia.org/
https://www.ijert.org/

# 2. Overall Description

## 2.1 Product Perspective

The "Birdcall Recognition" system, as outlined in the Software Requirements Specification (SRS), is a software product designed with a clear perspective within the context of machine learning and audio processing applications. It operates within a broader ecosystem of wildlife monitoring and biodiversity research, aiming to address a specific need—automated bird species identification based on vocalizations.

Within this perspective:

Integration with Biodiversity Research and Conservation: The product is positioned as a valuable tool for ornithologists, wildlife researchers, and conservationists who seek non-invasive methods to monitor bird populations and study biodiversity. It aligns with the broader goals of understanding and preserving avian species diversity.

Data-Driven Approach: The system operates in a data-centric manner, emphasizing the importance of high-quality audio datasets. It assumes the availability of birdcall audio recordings, acknowledging that data quality directly impacts the system's accuracy. Thus, the product perspective underscores the collaboration between technology and ecological science.

Enhancement of Manual Efforts: The "Birdcall Recognition" system complements and enhances the efforts of experts in the field. It does not replace human expertise but provides an automated and efficient means of processing large volumes of audio data. This perspective recognizes that technology can significantly augment the capabilities of ornithologists and researchers.

Position within Machine Learning: From a technical standpoint, the system is situated within the realm of machine learning and artificial intelligence. It harnesses the power of algorithms and models to recognize complex audio patterns and make species classifications. As such, it leverages contemporary advances in machine learning techniques for audio signal processing.

Component Integration: Within the product perspective, the integration of two core components, Exploratory Data Analysis (EDA) and Audio Feature Extraction (Audio FE), is crucial. EDA serves as the initial step for data understanding and preprocessing, ensuring that the data is well-prepared for Audio FE, which focuses on feature extraction for classification. The synergy between these components contributes to the system's effectiveness.

Expandability and Future Development: The "Birdcall Recognition" system is designed with the potential for future growth and enhancements. This perspective recognizes that the project's scope may evolve over time to incorporate additional features, machine learning models, or compatibility with new datasets.

## 2.2 Product Functions

The "Birdcall Recognition: EDA and Audio Feature Extraction" system, as outlined in the Software Requirements Specification (SRS), encompasses a range of essential functions, each serving a distinct purpose in achieving the project's goal of accurate bird species identification based on vocalizations.

Exploratory Data Analysis (EDA): EDA is a foundational function that serves as the initial step in data preprocessing. Its primary purpose is to facilitate a comprehensive understanding of the birdcall audio dataset. EDA employs statistical and visual techniques to analyze the data, revealing patterns, variations, and key insights within the audio recordings. It identifies potential outliers, ensures data quality, and provides valuable input for subsequent processing steps. EDA contributes to data preparation, ensuring that the dataset is well-suited for machine learning-based classification.

Audio Feature Extraction (Audio FE): Audio FE is a crucial function responsible for transforming raw birdcall audio data into structured sets of audio features. These features encapsulate relevant acoustic characteristics, such as spectrograms, mel-frequency cepstral coefficients (MFCCs), and other distinctive audio traits. The primary objective of Audio FE is to create feature vectors that succinctly represent the unique vocalizations of various bird species. These feature vectors are essential inputs for machine learning models used in bird species identification. Audio FE enhances the discriminative power of the data, allowing for more accurate species classification.

Bird Species Identification: The central and ultimate function of the system is bird species identification, driven by machine learning algorithms. This function involves the training, validation, and deployment of machine learning models capable of recognizing and classifying bird species based on their vocalizations. The models utilize the audio features extracted by Audio FE to make accurate predictions. The identification process adheres to the principles of supervised learning, where models are trained on labeled data. Additionally, model evaluation and performance optimization are integral components of this function to ensure reliable and precise species identification.

These functions operate in concert to achieve the overarching goal of "Birdcall Recognition: EDA and Audio Feature Extraction." EDA ensures a thorough exploration of the data, Audio FE prepares the data for machine learning, and bird species identification serves as the ultimate outcome. Together, these functions empower the system to make significant contributions to ornithology research, wildlife conservation, and biodiversity monitoring by facilitating non-invasive bird species identification through audio analysis.

## 2.3 User Classes and Characteristics

Identify the various user classes that you anticipate will use this product. User classes may be differentiated based on frequency of use, subset of product functions used, technical expertise, security or privilege levels, educational level, or experience. Describe the pertinent characteristics of each user class. Certain requirements may pertain only to certain user classes. Distinguish the most important user classes for this product from those who are less important to satisfy.

## 2.4 Operating Environment

The "Birdcall Recognition: EDA and Audio Feature Extraction" system operates within a defined operating environment that encompasses both the technical and ecological aspects necessary for its successful execution. This environment is carefully delineated in the Software Requirements Specification (SRS) to ensure optimal performance and functionality.

*Technical Environment:*

Hardware: The system is designed to be hardware-agnostic, capable of running on standard computing infrastructure. It is compatible with a range of hardware configurations, from desktop computers to cloud-based servers. The choice of hardware may depend on the scale of data processing and the computational requirements of machine learning algorithms.

Operating System: The software components of the system are developed to be platformindependent, supporting major operating systems such as Windows, macOS, and various Linux distributions. This ensures accessibility and flexibility in deployment.

Software Dependencies: The system relies on a stack of software dependencies, including programming languages (e.g., Python), audio processing libraries (e.g., Librosa), and machine learning frameworks (e.g., TensorFlow or PyTorch). The specific versions and configurations of these dependencies are detailed in the SRS to maintain compatibility.

*Ecological Environment:*

Birdcall Audio Data: The ecological environment encompasses the natural habitat and ecosystems where birdcall audio data is collected. This data is a critical input to the system and should adhere to ethical and ecological standards. The SRS specifies the expected format, quality, and ethical considerations for the birdcall audio dataset.

Data Collection Devices: In the field, data collection devices, such as audio recorders or sensor networks, are used to capture birdcall recordings. The system must be compatible with these devices and their associated data formats. Additionally, guidelines for ethical data collection and preservation are addressed in the SRS.

Human Expertise: Ornithologists, field researchers, and wildlife experts are essential components of the ecological environment. Their domain knowledge is invaluable for annotating and labeling birdcall audio data. The system should be designed to facilitate collaboration with experts to ensure accurate data labeling and model training.

*Interactions between Technical and Ecological Environments:*

The "Birdcall Recognition" system effectively bridges the technical and ecological environments. It ingests raw birdcall audio data collected in the field, which is subsequently processed using the system's EDA and Audio FE components. This processed data is then used to train and deploy machine learning models within the technical environment, enabling species identification. The results of these classifications are valuable to the ecological environment, contributing to ornithology research, wildlife conservation, and biodiversity monitoring.

## 2.5 Design and Implementation Constraints

The design and implementation of the "Birdcall Recognition: EDA and Audio Feature Extraction" system are subject to specific constraints that impact its development, functionality, and deployment. These constraints, as defined in the Software Requirements Specification (SRS), play a pivotal role in shaping the project's design and influencing implementation decisions.

Data Availability and Quality: One of the most significant constraints is the availability and quality of birdcall audio data. The effectiveness of the system heavily depends on the availability of comprehensive and well-labeled datasets. Inaccurate or incomplete data can hinder model training and compromise classification accuracy. Ensuring a reliable source of high-quality birdcall audio data is a fundamental challenge.

Computational Resources: The processing demands of the system, especially during Exploratory Data Analysis (EDA) and Audio Feature Extraction (Audio FE), necessitate substantial computational resources. To address this constraint, hardware scalability and optimization strategies are essential to ensure that the system can handle large audio datasets efficiently.

Expert Annotation: The accuracy of the system's machine learning models relies on expert annotations and labels for training data. Collaborating with ornithologists and domain experts for data annotation can be time-consuming and resource-intensive. Coordination with experts and adherence to their schedules may pose constraints on project timelines.

Model Training and Validation: Training and validating machine learning models for bird species identification require significant computational power and time. Constraints related to available computing resources and timeframes may impact the complexity and scale of the models that can be developed and deployed within the system.

Ethical Considerations: Ethical considerations related to data collection, wildlife monitoring, and conservation efforts impose constraints on the system's operation. These constraints may include adherence to ethical standards in data collection practices, ensuring that the system's usage aligns with conservation objectives, and respecting legal and ethical guidelines concerning birdcall recordings.

Compatibility: Ensuring compatibility with various audio recording devices and formats used in the field poses a practical constraint. The system must be designed to accommodate a range of data sources and configurations to maximize its utility in different ecological settings.

Scalability: As the system's user base and data volume grow, scalability constraints must be addressed. The system's architecture should allow for easy scalability to accommodate larger datasets and increasing processing demands.

Security Considerations: The model must be developed with security considerations in mind. This includes the protection of the data collected and processed, as well as the protection of the system from malicious attacks.

Design Conventions and Programming Standards: The model must be developed in accordance with design conventions and programming standards specified by the customer. This will ensure consistency and maintainability of the code, and make it easier for the customer to maintain and update the software in the future.

## 2.6 User Documentation

User documentation plays a vital role in ensuring that users can effectively interact with and utilize the "Birdcall Recognition: EDA and Audio Feature Extraction" system. As outlined in the Software Requirements Specification (SRS), user documentation encompasses a comprehensive set of materials designed to support users at various levels of expertise in their interactions with the system.

User Manuals: The cornerstone of user documentation is the provision of user manuals. These manuals are designed to cater to different user classes and their specific needs. They are detailed, step-by-step guides that walk users through the entire process of using the system, from data input and processing to obtaining classification results. The manuals are structured logically, with chapters or sections corresponding to different system functions, such as data preparation, feature extraction, and species identification.

Installation Guides: To assist users in setting up the system, installation guides are provided. These guides outline the software and hardware prerequisites, installation procedures, and configuration steps. They are designed to ensure a smooth setup process for both technical and non-technical users.

Troubleshooting Resources: Recognizing that users may encounter issues or errors during system operation, the user documentation includes troubleshooting resources. These resources consist of a comprehensive list of frequently asked questions (FAQs), known issues, and their resolutions. They empower users to resolve common challenges independently.

Best Practices and Tips: To enhance user proficiency and system efficiency, the documentation includes best practices and tips. These recommendations cover topics such as data collection guidelines, optimization techniques, and strategies for improving classification accuracy. Users can leverage these insights to maximize the system's effectiveness.

Reference Materials: A reference section provides users with a quick lookup for system commands, parameters, and key concepts. This reference material assists users in navigating the system efficiently and is especially valuable for experienced users who require rapid access to specific information.

User Support and Contact Information: The user documentation includes contact information for user support and assistance. Users can reach out for technical support, report issues, or seek clarification on any aspect of system operation.

## 2.7 Assumptions and Dependencies

The successful development and operation of the "Birdcall Recognition: EDA and Audio Feature Extraction" system, as outlined in the Software Requirements Specification (SRS), are contingent upon a set of assumptions and dependencies that are intrinsic to the project's context and functionality.

•Data availability: The model will require large amounts of labeled data of potholes on roads for training and validating the model.

- Hardware requirements: The model will require high-performance computing resources such as GPUs for efficient and effective training.
- Image quality: The quality of images captured by the camera used to collect data will affect the accuracy of the model.
- Quality of annotated data: The accuracy of the annotations provided for the data will directly impact the model's performance.
- Technical expertise: The team developing the model will need to have expertise in deep learning, computer vision, and image processing.
- Dependency on external libraries: The model may rely on existing libraries such as TensorFlow or PyTorch for implementation, and their updates could impact the model.
- Integration with existing systems: The model may need to be integrated with other existing systems, such as road maintenance systems, to provide real-time updates on potholes and garbage.
- Privacy and security: There may be privacy and security concerns around collecting and storing data, which will need to be addressed while developing the model.
- Model Training: The system's machine learning models are dependent on the availability of labeled data for training and validation. Timely access to annotated data is essential for model development.

# 3. External Interface Requirements

## 3.1 User Interfaces

The "Birdcall Recognition: EDA and Audio Feature Extraction" system is designed with user interfaces that facilitate user interactions, data input, processing, and retrieval of classification results. These user interfaces, as specified in the Software Requirements Specification (SRS), play a crucial role in ensuring that users can effectively harness the system's capabilities.

Data Input: Users can easily upload birdcall audio recordings through the GUI. The interface provides options for single-file uploads or batch uploads to process multiple audio recordings simultaneously.

Configuration Settings: The GUI allows users to configure various settings related to data preprocessing, feature extraction, and model selection. These settings can be adjusted to tailor the system's behavior to specific research needs.

Visualization: Visualizations generated during the Exploratory Data Analysis (EDA) phase are presented through the GUI. Users can explore data patterns, distribution plots, and summary statistics to gain insights into the input dataset.

Classification Results: Once audio processing and species identification are complete, the GUI displays classification results. Users can view detailed reports, including the recognized bird species and associated confidence scores.

User Assistance: Help features, tooltips, and user guidance are integrated into the GUI to provide assistance and ensure that users can navigate the system efficiently.

Command-Line Interface (CLI): In addition to the GUI, the system offers a command-line interface (CLI) designed for users who prefer a command-line environment or require batch processing capabilities. The CLI enables users to execute system commands and workflows programmatically, making it suitable for automation and advanced users who seek script ability.

API Integration: For seamless integration with existing workflows and applications, the system includes an application programming interface (API). This API allows developers and researchers to programmatically interact with the system's functionalities, including data ingestion, processing, and species identification. It offers flexibility for custom integrations and research-driven workflows.

## 3.2 Hardware Interfaces

The "Birdcall Recognition: EDA and Audio Feature Extraction" system interfaces with specific hardware components to enable the acquisition and processing of birdcall audio data. These hardware interfaces, as outlined in the Software Requirements Specification (SRS), are integral to the system's functionality and performance.

Audio Recording Devices: The primary hardware interface involves audio recording devices used for data collection in the field. These devices include specialized birdcall recorders, microphones, and sensor networks. The system assumes compatibility with a variety of audio recording hardware to accommodate different ecological settings and research scenarios.

External Storage Devices: Users may utilize external storage devices, such as external hard drives or network-attached storage (NAS), to store large volumes of birdcall audio recordings. The system's data input interfaces should facilitate the seamless connection and data retrieval from these storage devices.

GPU Acceleration: The system can benefit from hardware interfaces that support Graphics Processing Unit (GPU) acceleration. Machine learning models used for bird species identification may be optimized to leverage GPUs for faster processing. The system should detect and utilize available GPU resources if present in the user's hardware configuration.

Sensor Networks: In cases where sensor networks are deployed for continuous audio monitoring in ecological settings, the system should interface with these networks to access real-time audio streams. This hardware interface enables real-time analysis and species identification for ongoing monitoring efforts.

API Integrations: For advanced users and developers, the system's hardware interfaces extend to application programming interfaces (APIs) that allow for custom hardware integrations. This flexibility enables users to interface the system with specialized data acquisition and processing hardware relevant to their research.

Compatibility Considerations: The system's hardware interfaces are designed to ensure compatibility with a wide range of hardware configurations and devices commonly used in ornithology research and field data collection. Hardware requirements and recommendations are specified in the SRS to guide users in selecting suitable equipment.

In conclusion, the "Birdcall Recognition: EDA and Audio Feature Extraction" system embraces various hardware interfaces to accommodate the diverse needs and preferences of users engaged in ornithology research, wildlife conservation, and biodiversity monitoring. These interfaces empower users to seamlessly integrate the system into their data collection and processing workflows, ultimately enhancing the efficiency and effectiveness of birdcall audio analysis.

## 3.3 Software Interfaces

The "Birdcall Recognition: EDA and Audio Feature Extraction" system integrates with various software interfaces, libraries, and frameworks to enable data processing, analysis, and machine learning. These software interfaces, as specified in the Software Requirements Specification (SRS), are essential for the system's functionality and effectiveness.

Audio Processing Libraries: The system interfaces with audio processing libraries and frameworks such as Librosa, PyDub, and Soundfile. These libraries provide essential functions for reading, processing, and analyzing birdcall audio recordings. The system leverages these interfaces to extract audio features and conduct exploratory data analysis (EDA).

Machine Learning Frameworks: To train and deploy machine learning models for species identification, the system interfaces with popular machine learning frameworks such as TensorFlow, PyTorch, and Scikit-Learn. These frameworks provide the necessary tools for model development, training, and evaluation.

Data Visualization Tools: Data visualization is a key aspect of exploratory data analysis (EDA). The system interfaces with data visualization libraries such as Matplotlib and Seaborn to create informative plots, charts, and visualizations that assist users in understanding the characteristics of the birdcall audio data.

Data sharing mechanism: Data shared across software components: The input images and the results of the model's predictions are stored in the database and can be accessed by other software components. Implementation constraint: Access to the database should be secure and controlled, to maintain the privacy and security of the data.
API Protocols: Detailed API protocols are documented in the API documentation, which can be used by developers to integrate the deep learning model into their applications

In summary, the "Birdcall Recognition: EDA and Audio Feature Extraction" system embraces a diverse array of software interfaces and integrations to accommodate the varied needs of users engaged in ornithology research, wildlife conservation, and biodiversity monitoring. These interfaces enable seamless data processing, analysis, and collaboration, ultimately contributing to the system's utility and versatility.

## 3.4 Communications Interfaces

The "Birdcall Recognition: EDA and Audio Feature Extraction" system incorporates communication interfaces to enable data exchange, collaboration, and connectivity with external systems, researchers, and stakeholders. These communication interfaces, as specified in the Software Requirements Specification (SRS), facilitate seamless interaction and information sharing within the context of ornithology research and conservation efforts.

Data Import and Export: The system provides communication interfaces for importing and exporting data. Users can upload birdcall audio recordings into the system via web-based interfaces or file uploads. After processing, the system offers options to export results, reports, and processed data for further analysis or sharing.

Data Sharing and Data Access Control: In cases where data sharing is involved, the system provides interfaces for controlling data access and permissions. Researchers can define access levels and restrictions to ensure data privacy and security. External collaborators or stakeholders may access specific data subsets or reports based on predefined permissions.

E-mail: If the system sends notifications or updates via email, the requirements for email communication should be defined. This includes email address formats, message formats, and security requirements such as encryption.

Web browser: If the system is accessed through a web browser, the requirements for web browser communication should be defined. This includes browser compatibility, message formatting, and security requirements such as SSL encryption.

Network Server Communications Protocols: The communication between the deep learning model and the server should be defined. This includes the protocol used (such as FTP or HTTP), data transfer rates, and synchronization mechanisms.

Electronic Forms: If the system requires electronic forms for data entry or retrieval, the requirements for electronic form communication should be defined. This includes form formats, security requirements such as encryption, and data transfer mechanisms.

Communication Standards: The standards used for communication between the deep learning model and other software components should be defined. This includes communication protocols such as FTP or HTTP, and any data exchange formats used.

Real-Time Data Streaming: In ecological settings where real-time data collection is critical, the system interfaces with data streaming technologies. This allows for the continuous ingestion and processing of audio streams from sensor networks or remote field devices. Real-time data streaming enhances the system's capacity for live monitoring and instant species identification.

# 4. System Features

System Feature as outlined in the Software Requirements Specification (SRS), encompasses the critical functionality of Exploratory Data Analysis (EDA). EDA is the foundational process within the "Birdcall Recognition: EDA and Audio Feature Extraction" system, serving as the initial step in understanding and preparing the birdcall audio data for subsequent processing and analysis.

## 4.1 System Feature 1

Exploratory Data Analysis (EDA): This foundational component empowers users to gain a profound understanding of their birdcall audio data. It includes data summary statistics, data visualization tools (e.g., waveform and spectrogram analysis), and data filtering for noise reduction. Users can also recognize acoustic patterns, annotate audio segments, and perform exploratory statistics to uncover trends, enhancing data quality and informed decision-making.

## 4.2 System Feature 2

Audio Feature Extraction (Audio FE): The system facilitates the extraction and engineering of relevant audio features crucial for species differentiation. Users have the flexibility to customize feature selection, ensuring that the most informative attributes are utilized in analyses.

## 4.3 System Feature 3

Machine Learning Model Training: Seamless integration with machine learning frameworks allows users to develop and train species identification models using labeled data. Deep learning algorithms are also available for optimizing model accuracy and performance.

## 4.4 System Feature 4

Pattern Recognition: EDA includes algorithms for pattern recognition in birdcall audio. Users can identify recurring acoustic patterns, vocalization types, or common call structures.

## 4.5 System Feature 5

Quality Control: EDA facilitates data quality control by enabling users to detect and address issues such as background noise, recording artifacts, or incomplete recordings. This step enhances the reliability of subsequent analyses.

## 4.6 System Feature 6

User-friendly Interface: The model should have a user-friendly interface that is easy to use and navigate, making it accessible to all users, regardless of their technical expertise.

## 4.7 System Feature 7

Scalability: The model should be scalable, allowing it to accommodate increasing amounts of data and improve its accuracy over time.

## 4.8 System Feature 8

Robustness: The model should be robust and able to handle different types of road conditions, lighting, and weather conditions

## 4.9 System Feature 9

Cost-effectiveness: The model should be cost-effective, making it accessible to different levels of government, organizations, and communities.

## 4.10 System Feature 10

Bird call recognition: EDA and Audio FE" main use:- It primarily assists in bird species identification rather than population estimation. This system is designed to analyze birdcall audio data, helping researchers and ornithologists identify the species of birds based on their vocalizations. While it contributes significantly to species identification, population estimation typically involves more extensive data collection methods, such as bird surveys and statistical modeling, to assess the abundance and distribution of bird populations within specific ecosystems. The audio analysis provided by this system is a valuable component of broader efforts to monitor and conserve bird species, but it is just one part of the comprehensive toolkit used for population estimation and ecological studies.