Cardiff Metropolitan University

Cardiff School of Technology

BSc Software Engineering

BIRDY

(AI-Based Bird Sound Prediction Application)

Submitted in September

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By

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This dissertation is submitted in partial fulfillment of the requirements for the degree of
Bachelor of Science in Software Engineering (BSc SE)

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(AI-Based Bird Sound Prediction Application)

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A PROJECT SUBMITTED TO

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ACKNOWLEDGMENT

Developing an AI web application for bird sound detection has been difficult but immensely satisfying. Without the help and direction of several people and organizations, this endeavor would not have been feasible.

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I would want to express my gratitude to everyone who helped with this initiative, both directly and indirectly. This accomplishment would not have been possible without your encouragement and support.

ABSTRACT

This project is to carry out a comprehensive investigation of bird species within a certain geographic area, emphasizing the ecological roles, behavioral patterns, and environmental stresses that these species encounter. We want to investigate the complexities of bird migration, food ecology, reproductive strategies, and interspecies interactions using a combination of field observations, remote sensing technology, and data analytics.

The study makes use of cutting-edge instruments including drone technology to assess nesting sites with the least amount of damage to natural environments, bioacoustic sensors to examine communication patterns, and GPS tracking devices to monitor migratory paths. We will also evaluate the effects of habitat fragmentation, human activity, and climate change on bird populations in an effort to determine the ways in which these variables affect the distribution and survival of certain species.

The project's main goals are to identify crucial habitats for threatened and endangered species, comprehend the function of birds as ecological indicators, and create conservation and restoration plans for these areas. In order to promote community involvement in conservation activities and increase public knowledge of the value of avian biodiversity, public engagement will also play a big role.

The results of this study will benefit the field of ornithology as a whole by providing insightful information that can direct environmental management strategies and conservation policies. This research emphasizes the connection between biodiversity and the general health of our world by advocating for the protection of bird species and their environments.

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01.INTRODUCTION

The goal of the bird sound recognition project is to create an AI-driven online application that can recognize different kinds of birds based on audio recordings. The technology improves birding and research experiences by providing precise and real-time bird sound classification through the use of machine learning techniques.

01.01. BACKGROUND STUDY

Birds are essential to the preservation of ecological balance because they disseminate seeds, act as pollinators, and control bug populations as predators. Their sensitivity to environmental changes makes them useful bioindicators that shed light on the state of ecosystems. However, habitat loss, pollution, climate change, and other human influences are causing major decreases in bird populations worldwide. Studies conducted by groups like the International Union for Conservation of Nature (IUCN) and BirdLife International indicate that about 14% of bird species are thought to be in danger of going extinct.

Many bird species' migratory paths have been disrupted by the loss of vital habitats brought about by the world's growing urbanization and deforestation. Bird populations are forced to adapt to new surroundings or risk extinction because wetland, forest, grassland, and coastal regions that historically offered vital supplies for breeding, foraging, and shelter have either been diminished or degraded. The timing and routes of long-distance migration have been altered by temperature changes brought about by climate change, leaving certain species without adequate habitats at crucial junctures in their journey.

In ornithology, a number of seminal studies have examined how birds have adapted their behavior to changing settings. Though extremely adaptive, some species of birds are more vulnerable than others because of their specific habitats and eating habits, according to research. Bird migration and behavior studies has undergone a revolution thanks to the development of technologies like satellite telemetry and bioacoustics, which have provided previously unheard-of insights into the life cycles and interactions of birds with their surroundings. With the use of these technologies, scientists can now monitor bird movements in real time and gather enormous datasets that help build predictive models for the preservation of birds.

Furthermore, the conservation movement has accelerated in the last several years, emphasizing the need to preserve vital habitats and migratory corridors. Bird sanctuaries and protected areas have been established as a result of national conservation activities and international accords like the Convention on Migratory Species (CMS). Many species, particularly those with restricted ranges or those impacted by habitat fragmentation and human encroachment, are nevertheless vulnerable in spite of these efforts.

By expanding on previous studies in avian ecology and conservation biology, this study seeks to close information gaps regarding the unique challenges that individual bird species face in a given area. We want to offer fresh perspectives that help guide successful conservation plans and policy choices by combining contemporary tracking technology, behavioral research, and habitat analysis. The results of this study will support international initiatives to preserve the biodiversity of birds and guarantee the preservation of important habitats.

01.02. PROBLEM STATEMENT

Identifying different species of birds based solely on their vocalizations poses considerable difficulty for both novice and expert ornithologists. This procedure has historically required a great deal of skill and knowledge, which may be difficult for beginners and time-consuming for professionals. A technology solution that can automate the identification process is needed, as it would give everyone interested in birdwatching and study an easily available and effective tool.

01.03. OBJECTIVE

This project's main goal is to undertake an extensive investigation of bird species, with a particular emphasis on their behavior, migratory paths, and ecological roles. The objective of the research is to produce useful information that can support the development of successful conservation plans. The following are the project's precise goals as stated:

Examine Bird Behavior and Ecology: This goal entails learning about the daily activities of various bird species, including their eating habits, mating schedules, and reproductive strategies. Gaining an understanding of these behaviors will help us understand how these birds support the ecosystem. Furthermore, to gain a deeper comprehension of the ecological functions these birds perform in managing insect populations, pollination, and seed dissemination, we will investigate predator-prey dynamics and interactions between different species.

Track Migration Patterns: Using GPS and satellite telemetry, the project's main goal will be to follow the migratory paths of a few chosen bird species. This will make it easier to chart their migration route through different regions and pinpoint important habitats that they use as rest stops. The project will also look at the time of migration, including how seasonal and climatic variables, including variations in temperature and rainfall patterns, impact the birds' migration routes.

Assess Habitat Use and Preferences: We will assess the quality and availability of vital resources, such as food, water, and nesting sites, in their surroundings in order to comprehend the preferences of various bird species with regard to their habitats. The research will highlight regions that need conservation by identifying important habitats that are necessary for survival and reproduction. Additionally, we want to identify the ecosystems that are most vulnerable to changes in the environment or human activities and suggest conservation measures to lessen those risks.

Examine Environmental and Human Effects: This goal entails determining how changes in the environment, such as deforestation and climate change, affect bird populations. We'll also look at how human activities affect bird species and their habitats, such as pollution, urbanization, and agricultural growth. In order to secure the long-term existence of threatened bird species, the project intends to propose suggestions for sustainable land use practices and habitat conservation by comprehending these implications.

01.04. SOLUTIONS

Creating Advanced Machine Learning Models: This project suggests creating advanced machine learning models designed especially for bioacoustic data in order to increase the precision of bird sound predictions. Large datasets of bird calls and songs can be used to train models, which will improve the system's capacity to identify different species and forecast future sounds depending on surrounding conditions. The time-frequency patterns in bird sounds will be analyzed using methods such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), which will increase the prediction accuracy in practical situations.

Building an Extensive Open-Access Database of Bird Sounds: Establishing a comprehensive database of bird sounds that incorporates variances based on location, season, and individual variations within species is a crucial step towards finding a solution. Accumulating sound recordings of superior quality from various environments will yield a substantial dataset for model testing and training. The volume and diversity of sound samples can be greatly increased by crowdsourcing recordings from citizen scientists and ornithologists, which enables more accurate forecasts in a variety of situations.

Integrating Environmental Data to Improve Predictions: The weather, habitat, and time of day are few examples of environmental elements that frequently affect bird vocalizations. The research will incorporate environmental data (such as temperature, humidity, and wind conditions) into the prediction models in order to increase the reliability of the predictions. The algorithm can more accurately and contextually anticipate when and where particular bird species are expected to vocalize by establishing a correlation between bird sounds and environmental factors.

Putting in Place Real-Time Sound Monitoring devices: Continuous data gathering and quick predictions of bird noises will be made possible by the installation of real-time acoustic monitoring devices in significant habitats. These systems may process audio input locally and deliver findings almost instantly by utilizing edge computing. Researchers and wildlife managers can learn a great deal about bird behavior and population trends without affecting the natural environment by incorporating real-time sound detection and prediction technologies into urban or conservation areas.

Encouraging Conservation With Sound Analytics: Technologies for sound prediction might be a useful asset for conservation initiatives. Conservationists can identify endangered species in particular places, track changes in bird activity, and keep an eye on population health by properly forecasting bird sounds. In order to apply sound analytics for early warning systems that identify habitat disturbances or bird population losses, this research suggests collaborating with conservation organizations. Additionally, by highlighting the existence of important species and their vocal activity, sound predictions can help guide habitat restoration efforts.

02. LITERATURE REVIEW

Bioacoustics, the study of bird noises, is becoming an important field of study in conservation biology and ornithology. Key markers of a species' presence, behavior, and surroundings are its vocalizations. Developments in machine learning and acoustic monitoring over the past few decades have created new opportunities for the analysis and prediction of bird noises, with uses ranging from species identification to conservation initiatives. The important research and scientific advancements that serve as the basis for bird sound prediction systems are highlighted in this article.

Research on Bird Vocalization and Bioacoustics: Birds employ vocalizations for communication with their young, defending their territories, and attracting mates, among other things. In order to comprehend the biological purposes and evolutionary relevance of bird songs, early bioacoustic research concentrated on cataloging and studying these sounds. The groundwork for understanding how genetics, environment, and social interactions affect bird song development was laid by Kroodsma's (1982) research on song learning and development in birds. Since then, a great deal of research has looked into the pitch, frequency, and rhythm of bird calls in order to categorize different species of birds and learn more about their behavior. Derryberry et al.'s (2020) recent study highlighted how environmental changes, such as urban noise pollution, are influencing bird vocalizations, changing communication patterns and possibly upsetting interactions between species.

Research on bird sounds has been transformed by the introduction of automated acoustic monitoring devices. The manual recording and identification processes of the early systems were time-consuming and restricted to certain periods. But because to developments in digital technology, it is now possible to continuously and instantly monitor bird sounds. Bird vocalizations can be remotely recorded and analyzed thanks to the use of devices like AudioMoth and ARBIMON (Acoustic Remote Biodiversity Monitoring Network), which have been installed in a variety of environments. These systems record long-term sound data, which can be used to monitor biodiversity, inventory species, and identify shifts in bird populations. Blumstein et al. (2011) provided important information for ecological study and conservation by demonstrating the efficacy of acoustic monitoring in remote locations through non-invasive methods.

Machine Learning in Bird Sound Recognition: In the past few years, machine learning methods have become more and more popular in the identification and forecasting of bird sounds. While human skill was required for traditional techniques of species identification, machine learning models—especially convolutional neural networks (CNNs) and recurrent neural networks (RNNs)—now enable automatic, highly accurate sound classification and prediction. By employing audio recordings to create an autonomous system for large-scale bird species identification, Stowell et al. (2015) showed that CNNs could be trained to distinguish minute variations in bird calls. Deep learning approaches have been used in other studies, such those by Lostanlen et al. (2019), to classify bird calls, with better recall rates and precision in a variety of audio situations.

Integration of Environmental elements in Sound Prediction: The significance of environmental elements in forecasting bird noises has been highlighted in a number of studies. The kind of habitat, the weather, the time of day, and even the season all influence how vocalized birds become. A study conducted in 2013 by Gasc et al. investigated how the ecological background of bird colonies affects the vocalizations that the birds make. Researchers can increase the precision of bird sound forecasts by integrating environmental data, such vegetation density or weather, into prediction algorithms. For real-world applications where acoustic surroundings are dynamic and ever-changing, this integration is especially crucial.

Opportunities and Difficulties in Predicting Bird Sounds:Even though bird sound prediction has come a long way, there are still a number of obstacles to overcome. The "cocktail party problem," in which several bird species vocalize at the same time and make it challenging for models to distinguish between various calls, is one significant problem. Research by Kahl et al. (2021) have investigated ways to use signal processing methods like noise filtering and source separation to get around this problem. Lack of thorough, excellent training datasets is another issue, particularly for uncommon or endangered species. But now that citizen science platforms like Xeno-canto and eBird from the Cornell Lab of Ornithology have grown, researchers have increased access to large and varied audio datasets for training prediction algorithms.

Applications in Ecological Monitoring and Conservation: The field of conservation biology greatly benefits from the ability to predict bird sounds. Conservationists can track population changes over time and spot patterns in the presence or absence of a species by automatically detecting and classifying bird species in massive databases. Research has demonstrated that sound monitoring is a non-invasive means of population monitoring that doesn't involve physical disturbance, as demonstrated by studies like those conducted by Kuhl et al. (2020) to track the presence of endangered species in isolated places. In addition, prediction models can help detect alterations in vocal activity brought on by environmental stressors like habitat loss or climate change, providing early warning indicators for conservation action.

03. PLANNING

03.01. FEASIBILITY REPORT

The suggested bird sound recognition system's viability and likelihood of success are assessed through a feasibility study. It includes scope, cost, timing, and technical viability, among other aspects.

COAST FEASIBILITY

Cost feasibility analysis entails examining the project's financial components. This entails projecting the start-up costs, continuing expenditures, and possible gains. The following evaluations are carried out to determine cost feasibility:

NET PRESENT VALUE(NPV)

By deducting the initial investment, net present value (NPV) computes the present value of cash flows over a given period of time.

$$NPV=\sum((1+r)\ t\ Ct) - C0$$

where:

- Ct = net cash inflow during the period
- r = discount rate

- t = number of time periods
- C0 = initial investment

RETURN ON INVESTMENT

ROI calculates the profit or loss in relation to the capital invested.

$$ROI = \text{Net Profit} / \text{Total Investment} \times 100$$

PAYBACK PERIOD

The amount of time it takes for net cash inflows to cover the investment is known as the payback period.

$$\text{Payback Period} = \text{Annual Cash Inflows} / \text{Initial Investment}$$

CALCULATION

LKR 50,000 is the initial investment (C0).
Net Cash Inflow (Ct) on an annual basis: LKR 15,000.
Rate of Discount (r): 5%
Project Length: Three weeks

NVP CALCULATION

NPV=(1+0.05)115,000+(1+0.05)215,000+(1+0.05)315,000+(1+0.05)415,000
+(1+0.05)515,000−50,000

NPV=14,285.71+13,605.44+12,957.56+12,344.34+11,756.51−50,000

NPV=64,949.56−50,000

NPV=14,949.56

ROI CALCULATION

ROI= (15,000×5) −50,000 / 50,000×100

ROI=75,000−50,000 / 50,000 ×100

ROI= 25,000 / 50,000 ×100

ROI=50%

SCOPE FEASIBILITY

In order to make that the project's goals and deliverables can be met within the specified parameters, scope feasibility looks at them.

OBJECTIVES

- Create a machine learning model to identify bird sounds.
- Construct an intuitive online application
- Assure prompt processing and great accuracy.

DELIVERABLES

- Machine learning model that has been trained.
- web application featuring a user-friendly UI.
- User manual and documentation.

TECHNICAL FEASIBILITY

The assessment of technical feasibility determines if the project can be completed with the current technology, expertise, and resources.

- Technology: TensorFlow, Keras, Python, and web development tools (HTML, CSS, JavaScript) are used.
- Proficiency in audio processing, web programming, and machine learning.
- Resources: Computational power, programming tools, and databases of bird sounds.

03.02. RISK ASSESMENT

Data Availability and Quality: The availability and quality of bird sound data is one of the main project hazards. Large, accurate, and diverse datasets are critical to the performance of machine learning models. Incomplete data, low audio quality, and background noise in the recordings could make it more difficult for the program to correctly anticipate bird sounds. The project will put a great priority on obtaining high-quality recordings, applying noise reduction strategies, and guaranteeing a diverse dataset through crowdsourcing and partnerships with bird sound databases like Xeno-canto in order to reduce this risk.

Model Accuracy and Overfitting: The possibility of overfitting or inadequate model generalization is another significant danger. In real-world settings, machine learning models may perform well on training datasets but poorly on fresh, unknown data. When models grow very skilled at identifying particular sound patterns, it's known as overfitting, and this can lower forecast accuracy in novel species or habitats. Regularization techniques will be used in the training, cross-validation, and comprehensive testing of the model on a variety of datasets from different environments in order to reduce this risk.

Environmental Noise Interference: Human activity, wind, and rain can all cause environmental noise to interfere with bird sound prediction systems. Bird vocalizations might be obscured by such noise, making it challenging for the system to recognize and anticipate sounds with accuracy. The project will use sophisticated noise filtering and sound separation algorithms to separate bird cries from ambient noise in order to mitigate this risk. Furthermore, a range of acoustic conditions will be tested to guarantee robustness in a variety of soundscapes.

Ethical and Legal Issues: The gathering and use of data may give rise to ethical and legal issues, particularly when recording equipment is placed on private or protected property. Without the proper authorization, recording bird noises in sensitive areas may give rise to legal issues or inadvertently disturb wildlife. In order to mitigate this risk, all data gathering will comply with applicable privacy and environmental legislation, and prior to doing any fieldwork, the necessary permits will be obtained from local authorities and landowners.

Technical Difficulties in Remote Areas: The installation of acoustic monitoring equipment may pose technical difficulties in remote or hard-to-reach areas. These difficulties may include keeping power supplies stocked, guaranteeing dependable data transmission, and shielding equipment from inclement weather. These restrictions may result in incomplete data sets and less accurate forecasts. The project will deploy weather-resistant, energy-efficient devices with data storage capabilities to reduce this danger and enable ongoing monitoring even in places with inadequate power or network connectivity.

Unpredictable Changes in Bird Behavior Owing to Climate Change: Other environmental stressors, such as climate change, may cause unpredictable changes in bird behavior, including vocalization patterns. These modifications may cause models to become out of date or less successful in the future at predicting bird sounds. The research will incorporate dynamic environmental data into the prediction models, enabling constant model updates and response to shifting conditions, to lessen this risk. Furthermore, as environmental conditions change, long-term monitoring will be essential for recording changing patterns in bird vocalizations.

03.03. SWOT

Strength:

Innovative Method: Predicting bird sounds using machine learning and artificial intelligence is a novel method that has the potential to revolutionize environmental monitoring and wildlife protection.
Real-world Impact: Data-driven ecological research, conservation initiatives, and the identification of bird species could all benefit from this study.

Technical Expertise: Exhibits a strong technical command of Java and AI-related technologies while demonstrating your ability in sound processing, data analysis, and system building.

Market Demand: As environmental problems become more well-known, there is a growing need for automated wildlife monitoring systems.

Weakness:

Data Availability: The number and quality of bird sound datasets may be a constraint, which could have an impact on the prediction's accuracy.

Complexity of Sound Processing: It might be difficult to achieve high prediction accuracy due to the variety of bird noises, particularly in various situations (such as background noise).

Project Scope: Due to resource constraints, the project may not be able to advance into new domains such as mobile app integration or real-time prediction.

Opportunities:

Working together with environmental agencies: Possibility of collaborations to improve the system with conservationists, wildlife organizations, or research teams.

Extension into Other Domains: It is possible to modify the sound prediction model to accommodate non-biological sounds, such as industrial sound monitoring, or other animal species.

Commercialization: If this research is improved, there may be business prospects. For example, the technology may be sold to parks, avian enthusiasts, or environmental groups.

Technological Progress: Using increasingly complex algorithms, you can further optimize and improve the model in light of the expanding trends in AI and deep learning.

Threats:

Rivals: Up-and-coming rivals in the wildlife monitoring space may create comparable systems, which would reduce your market share.

Technological Advancements: If AI continues to progress at its current rate, current technology may become antiquated if it isn't updated frequently.

Data Privacy and Ethical Issues: If the system penetrates sensitive locations, data privacy issues and the morality of utilizing AI for environmental monitoring may come up.

Finance and Resource Limitations: The project's progress may be hampered by a lack of funding or access to high-quality tools.

03.04. PESTAL ANALYISIS

Political:

Environmental Policies: The project may benefit from backing from government programs pertaining to biodiversity and wildlife conservation.

AI and Data Regulations: Adherence to data privacy and AI usage guidelines may have an impact on the development and implementation of systems.

Economic:

Opportunities for financing: Grants and financing for environmental AI initiatives may be available.

Development Costs: The project's capacity to be financially stable may be impacted by the price of tools, cloud services, and resources.

Social:

Public Interest: Project relevance is supported by growing public interest for environmental issues.

Collaborations: The project's societal impact may be increased by possible alliances with academic institutions and environmental organizations.

Technological:

Advances in AI and ML: As AI technology develops, system accuracy and performance can be increased.

Tools for Sound Processing: New technologies in audio processing have the potential to improve system dependability and efficiency.

Cloud Computing: System performance and scalability can be improved by having access to cloud services.

Environmental:

Conservation Efforts: The initiative is in line with international objectives for conservation and biodiversity.

Climate Change Monitoring: By keeping track of changes in bird populations, the technology could support research on climate change.

Legal:

Intellectual Property Protection: To safeguard the innovation, a patent or other IP protection may be required.

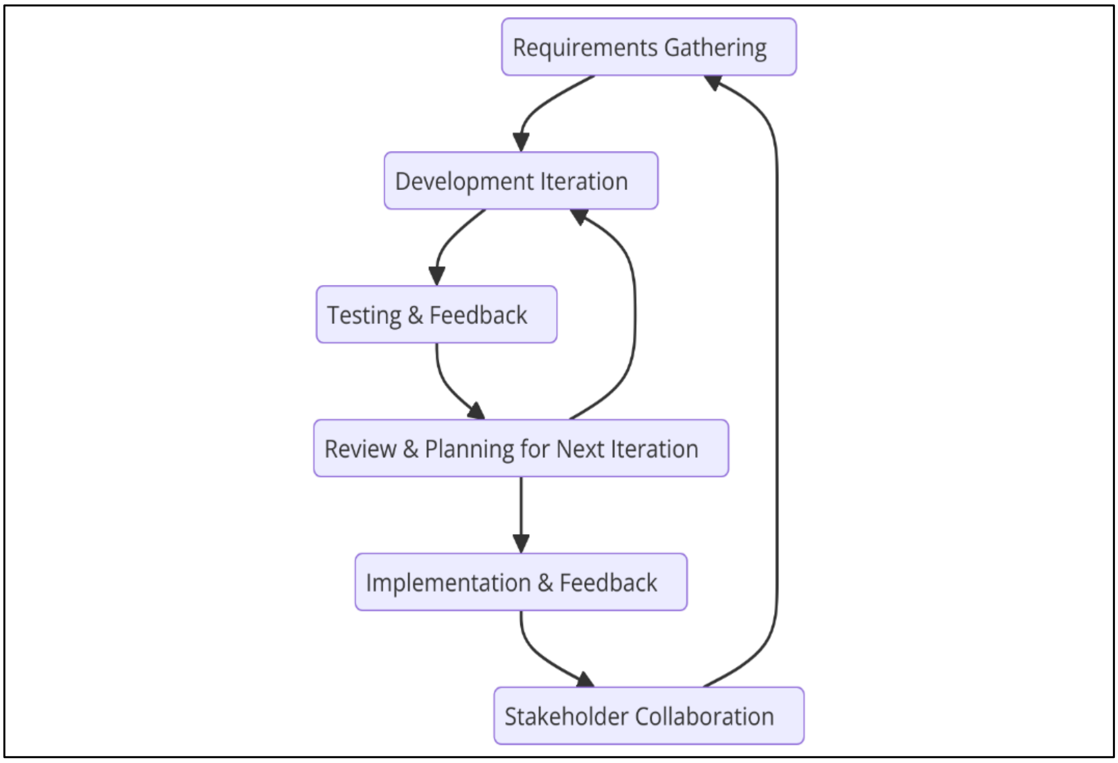
Data Privacy Laws: If the system is going to be commercialized, it is imperative that it comply with data protection laws such as GDPR.

03.05. LIFE CYCLE MODEL

The Agile approach is the development process paradigm that was chosen for this project. Agile is preferred because of its adaptability, iterative development methodology, and focus on input and cooperation from customers.

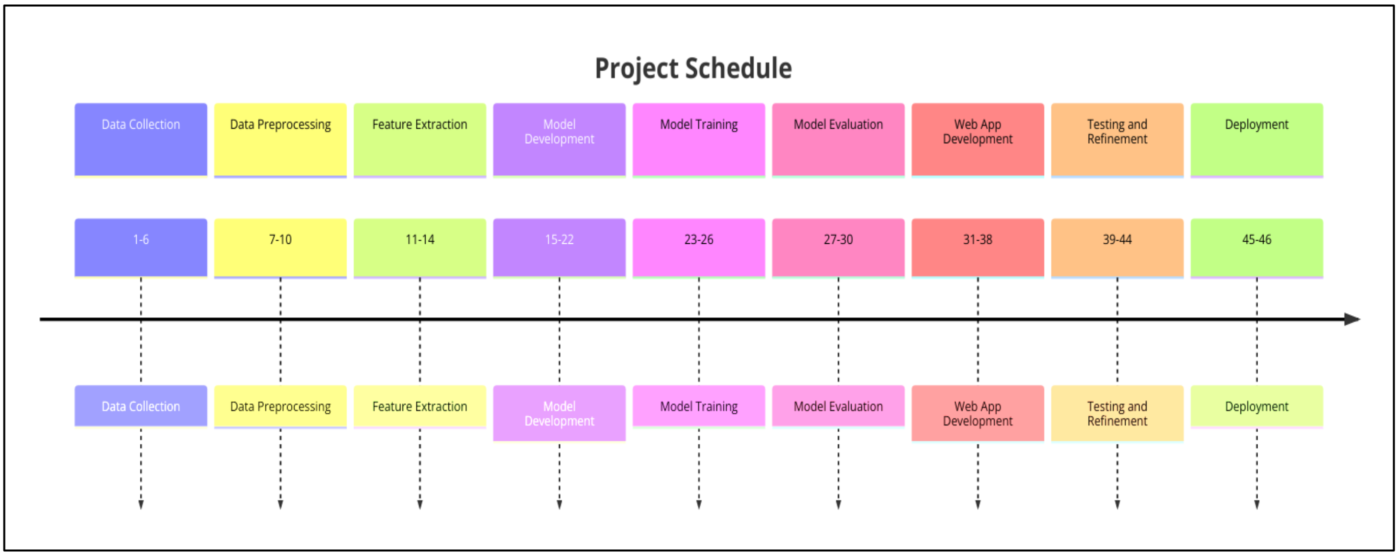
KEY FEATURES OF AGILE METHODOLOGY

- Iterative development is the process of creating software in tiny, controllable steps.
- Customer collaboration: Consistent communication with stakeholders to get their input and modify specifications.
- Flexibility: The capacity to adjust during the development process to required changes.
- Continuous Improvement: Examining and enhancing the product and development process on a regular basis.



03.06. TIME PLAN

The project's ability to be finished in a fair amount of time is evaluated by temporal feasibility. The tasks required, such as data gathering, model building, testing, and deployment, are taken into account while estimating the project timeline.



04. REQUIRMENTS GATHERING & ANALYSIS

04.01. REQUIREMENT GATHER TECHNIQUE USED FOR THIS PROJECT

Literature study: Finding current studies, approaches, and datasets pertaining to bird sound prediction is facilitated by conducting a literature study. This method offers a basic comprehension of the state of the art in the field.

Interviews with Stakeholders: Speaking with important parties including ornithologists, ecologists, and tech developers enables qualitative information about their requirements and project expectations to be gathered.

Surveys and Questionnaires: By distributing surveys to a larger group of people, such as researchers and birdwatchers, quantifiable information on their requirements and interests in relation to bird sound prediction can be gathered.

Workshops and Focus Groups: Setting up cooperative meetings with interested parties encourages ideation and brainstorming, allowing participants to prioritize needs and exchange experiences.

Prototyping and Feedback Sessions: By creating a working prototype of the prediction system and holding feedback sessions, stakeholders are able to see the project in concrete form and gain insight into its functionality and usability.

Field Observations: In order to make sure that the project is based on real-world information on bird vocalizations and environmental conditions, field observations are conducted.

04.02. QUESTIONNARIES

Questions for the Literature Review:

Which approaches are currently applied in the literature to anticipate bird sounds?
Which datasets are available, and what are their limitations?

Questions for Stakeholder Interviews:

What particular characteristics are you looking for in a bird sound prediction system?
What difficulties do you have when keeping an eye on bird populations?

Questions for surveys and questionnaires:

How frequently do you go bird watching or bird monitoring?
Which instruments do you now employ to identify bird sounds?

04.03. INTERVIEW

Overview:
Could you give a quick overview of your training and history in bird conservation or research?
What function do bird noises serve in your research or work?
Present Methods:
In your fieldwork, how do you currently recognize and track bird sounds?
Which devices or tools do you currently employ to identify bird sounds?
What problems do you have using these existing techniques?

Expectations and Needs:
What particular characteristics or qualities are you hoping to see in a system that predicts bird sounds?
To what extent does the precision of forecasts matter in your work? To what extent do you anticipate accuracy?
Are there any specific bird species or subspecies that you find difficult to distinguish by sound?

Performing the Interviews

Preparation: Make sure participants are aware of the project's goals and schedule interviews ahead of time.
While conducting the interview, set up a recording device (with permission) or take thorough notes.
Interviews should be held in a calm, relaxed atmosphere to promote candid conversation.
Follow-up: Express gratitude to the participant and provide a synopsis of the main ideas covered during the interview.
Think about providing project updates or letting them know how their input will be used.

04.04. SUMMARY OF INTERVIEW &QUESTIONS

An overview of the interviews

The purpose of the interviews is to obtain qualitative perspectives from ornithologists, conservationists, and technology developers who are active in bird research and conservation. Gaining insight into their requirements, hopes, and difficulties with reference to bird sound prediction systems is the main goal. Every interview will take place in a pleasant environment, either in person or over video conference, and will run for thirty to sixty minutes each. To guarantee a wide variety of viewpoints, participants will be chosen carefully, and the meetings will be either videotaped or written down to properly record the conversations. This procedure will assist in determining the essential components, issues, and useful uses for the suggested system, guaranteeing that it satisfies user needs and makes a significant contribution to conservation efforts.

An overview of the interview questions

Starting with the participants' backgrounds and experiences in bird research, the interview questions are designed to cover a variety of topics relating to bird sound prediction. Important topics of research include the methods used today to recognize and track bird noises, the equipment they utilize, and the difficulties they encounter. Questions on desirable features and accuracy levels of the prediction system will be posed to stakeholders. Inquiries will also focus on how participants see incorporating the system into their workflows and possible uses for it in conservation. Concerns about automated systems, including moral and legal issues, will also be covered in the interviews. In order to guarantee ongoing development and applicability, input on the system's design and the frequency of model updates will be requested.

04.05. FUNCTIONAL & NON-FUNCTIONAL REQUIREMENT

FUNCTIONAL REQUIREMENTS

Gathering of Data:

Bird noises from a variety of settings and locations must be able to be captured and stored by the system.

Input from many audio sources, including mobile devices, microphones, and databases already in place, should be supported.

Appropriate Categorization:

The system has to use machine learning methods to categorize recorded bird noises into distinct species or groups.

It ought to offer real-time sound classification as it's being recorded.

Interface User:

In order for users to engage with the system and access recorded sounds, classifications, and pertinent data, an intuitive user interface needs to be created.

It should be possible for users to look up and view the vocalization patterns of particular bird species.

Training of Prediction Models:

Labeled datasets should be able to be used to train prediction models on the system, allowing

for constant accuracy improvement.
It should be possible for users to submit fresh datasets for model retraining.

Integration of Environmental Data:
In order to improve prediction accuracy, the system needs to incorporate environmental data (such as temperature, humidity, and time of day).
In addition to sound recordings, users ought to be able to enter and display pertinent environmental parameters.

Reporting and Graphics:
Bird sound data should be visualized and reported by the system, along with trends over time and species distribution.
For additional analysis, users ought to be able to export data in a variety of formats (such as CSV and PDF).

NON- FUNCTIONAL REQUIREMENTS

Achievement:
With a minimum latency (less than two seconds for sound classification), the system ought to be able to process and categorize bird noises in real-time.
It should be able to process enormous amounts of audio data without seeing a noticeable drop in speed.

Scalability
The system needs to be scalable in order to handle more users and data without sacrificing functionality.
As user needs change, it should be able to accommodate new features and functionalities.

Usability:
To ensure that users with different technical backgrounds can utilize the system efficiently, the user interface needs to be simple to use and intuitive.
To help users comprehend and use the system, thorough documentation and tutorials should be offered.

Reliability:
During the collecting and processing of data, the system should provide high availability and

little downtime.
To stop data loss, it has to have backup and recovery systems.

Safety:
Robust security measures must be implemented by the system to safeguard sound recordings and private user information.
To limit access to those who are permitted exclusively, user authentication and permission must be in place.

Observance:
The system needs to abide by applicable data privacy and environmental laws, especially when it comes to gathering and using bird sound data.
It ought to adhere to the moral standards governing data collecting and study on wildlife.

05. SYSTEM DESIGN

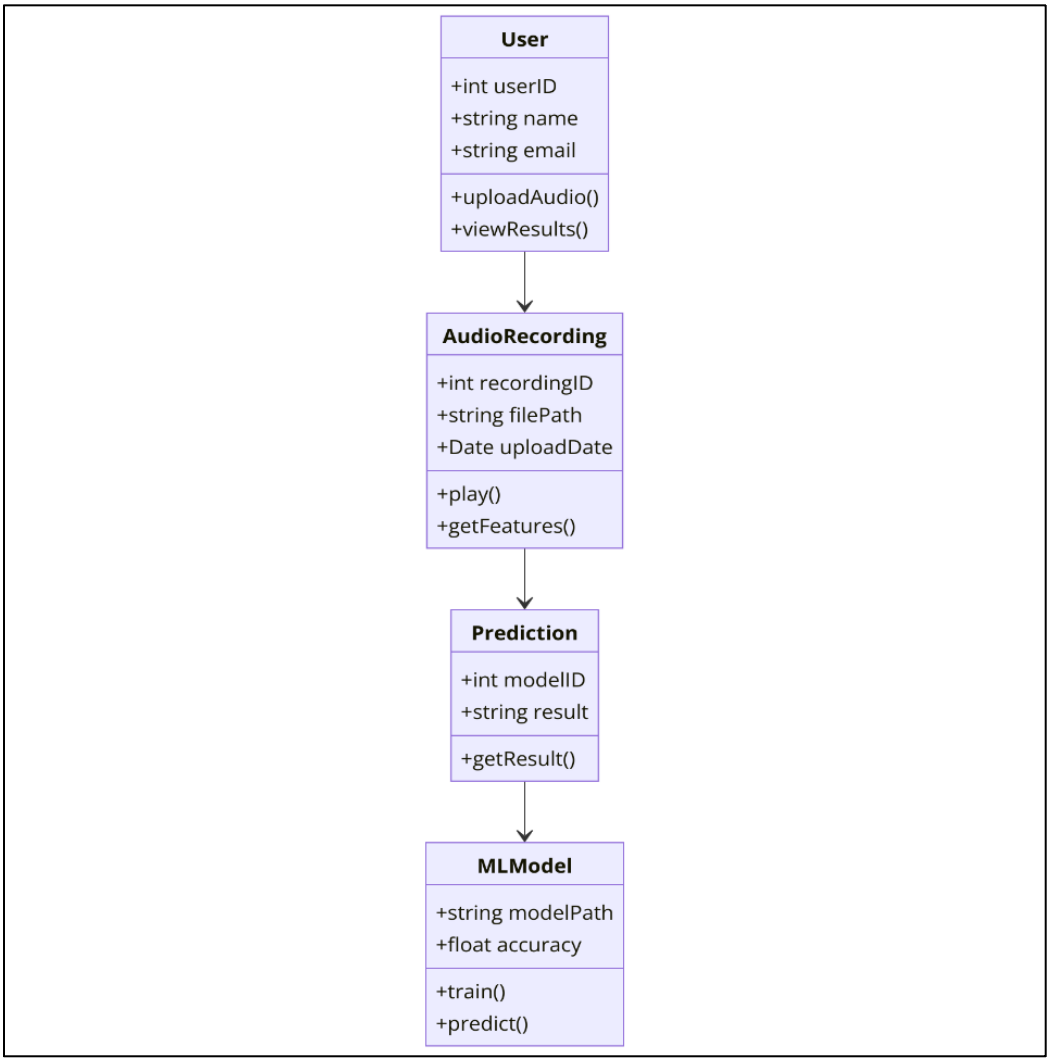
During the design phase, a schematic of the bird sound recognition system's architecture, parts, and functions is created. The system architecture, important diagrams, and database design are all covered in this chapter along with the system's overall design.

KEY COMPONENTS OF DESIGN

- System architecture: Specifies the hardware and software components as well as the overall high-level structure of the system.
- System Design: Uses a variety of diagrams to explain how components work together and interact.
- Database design describes the entities, relationships, and schema that make up the database's structure.

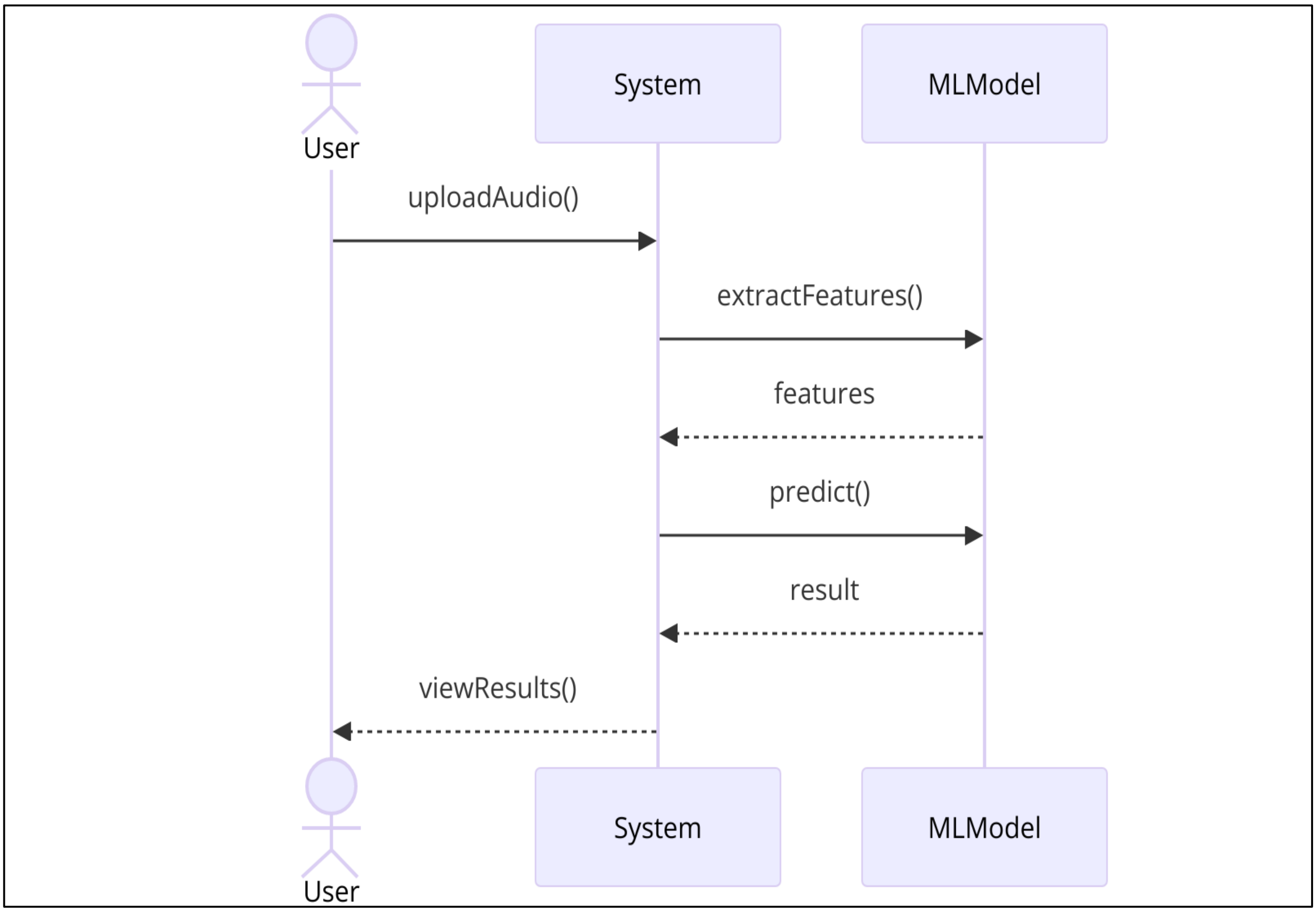
05.01. CLASS DIAGRAM

The class diagram, which illustrates the classes, their attributes, functions, and relationships, acts as a template for the bird sounds prediction system's static structure. Every class encapsulates data and functionality, representing a unique part of the system. For instance, the methods and properties of a BirdSound class might be classifySound(), analyzeFrequency(), and retrieveMetadata(), and the properties could be soundID, speciesName, recordingTime, and environmentalConditions. Another important class can be called User, which has methods for login, logout, and submitFeedback along with properties like userID, username, and userRole. Associations, aggregations, and inheritances are used to illustrate relationships between classes and show how various system components interact. A RecordingSession class, for example, may combine several BirdSound instances to show how sounds are organized throughout particular recording tasks.



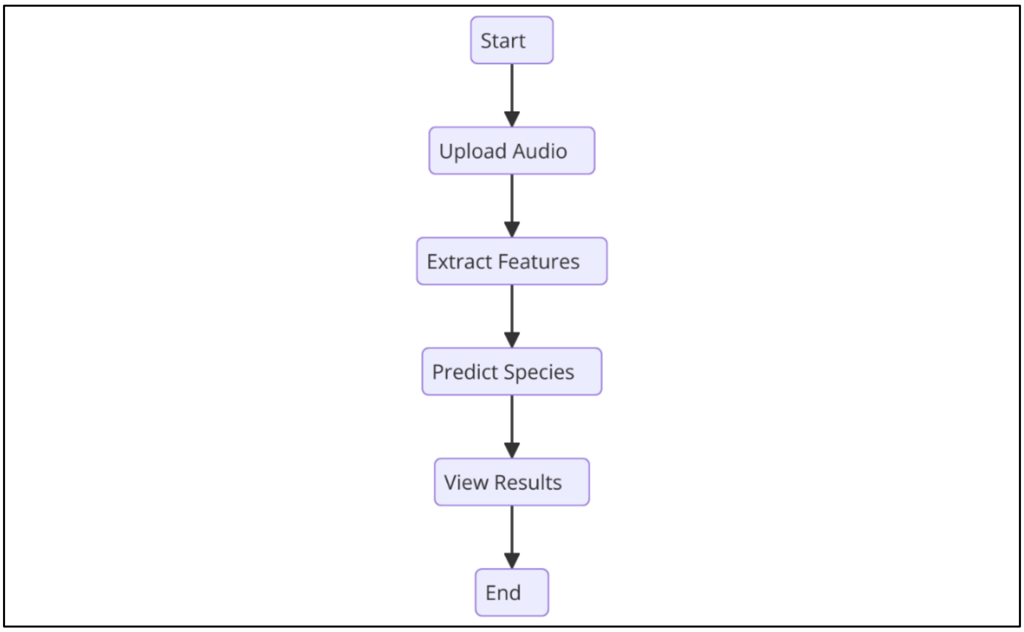
05.02. SEQUENCE DIAGRAM

The bird sounds prediction system's sequence diagram is a dynamic representation that shows the order in which messages are exchanged between objects in a particular use-case scenario. It offers a thorough understanding of how different parts work together throughout time to accomplish certain tasks. In the event when a user records a bird sound, for example, the diagram might show the messages that are sent between the User, Recorder, AudioProcessor, and Database. By giving the Recorder a startRecording() message, the User starts the interaction by starting the recording process. The AudioProcessor receives a processAudio() message to evaluate and categorize the sound after the Recorder delivers a saveAudio() message to the Database when the recording is finished.



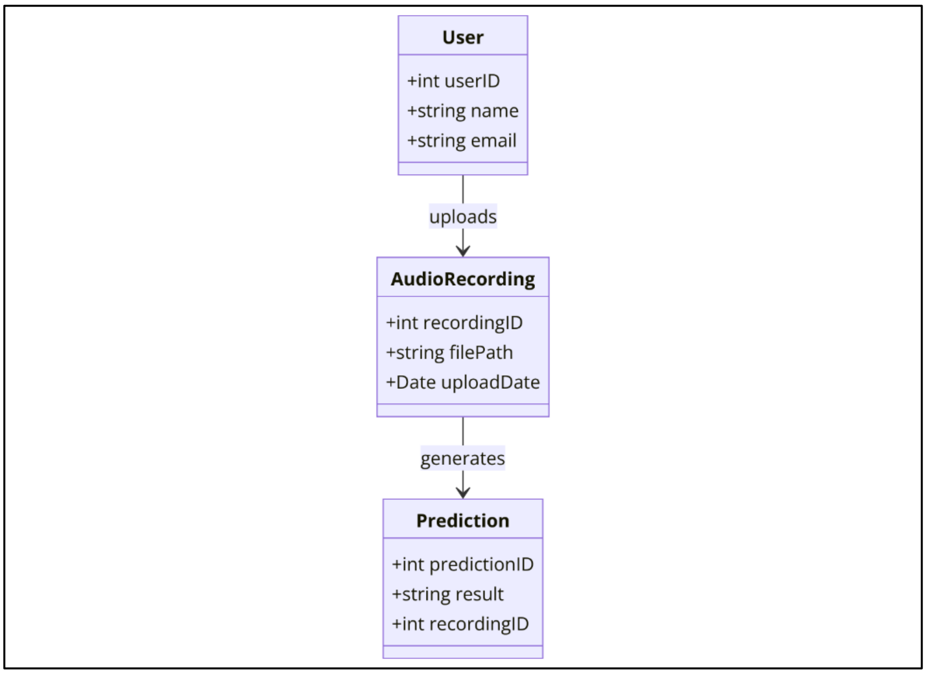
05.03. ACTIVITY DIAGRAM

The activity diagram effectively illustrates the workflow of the bird sounds prediction system by giving a visual depiction of the sequence of actions involved in a particular phase. This graphic shows the several steps and choices that must be made in a specific use case, such as recording and categorizing bird noises. Setting up the recording equipment and modifying the ambient conditions are the next steps once the user chooses to record a sound as the first activity. The figure shows concurrent processes, including the system monitoring background noise and collecting environmental data, while the recording starts. The feedback loops are also highlighted in the diagram, allowing the user to examine and edit their data or input in light of the categorization outcomes.



05.04. ER DIAGRAM

The bird sounds prediction system's Entity-Relationship Diagram (ERD) gives a thorough picture of all the data entities, including their attributes and relationships with one another. A crucial element of the system's data model is represented by each entity, including BirdSound, User, RecordingSession, and EnvironmentalData. To capture important details about each recorded sound, the BirdSound entity, for example, can have characteristics like soundID, speciesName, frequency, and recordingTime. Some attributes that describe the people interacting with the system, like userID, username, and user role, may be present in the User entity. The connections between these entities are shown as lines that show their interactions and linkages.



06. IMPLEMENTATION

The actual creation and installation of the bird sound recognition system take place during the implementation phase. This chapter describes the general strategy for putting the system into practice, including creating user interfaces and integrating different parts.

KEY COMPONENTS OF IMPLEMENTATION

01. System development involves writing code and putting the system's front-end interfaces, back-end services, and machine learning model together.
02. Developing and perfecting the user interfaces that allow users to communicate with the system is known as user interface design.
03. Testing and integration: Making sure all parts function as a whole and adhere to the set specifications.

USER INTERFACE

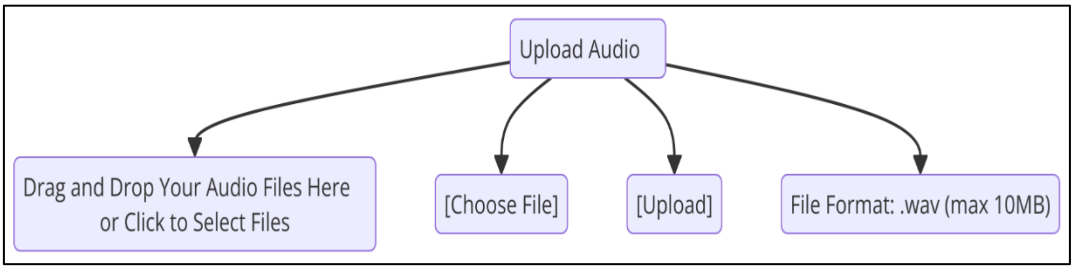
For users to interact with the bird sound recognition system, user interfaces are essential. They provide interfaces for both input and output that make it easier for users to interact and see the outcomes.

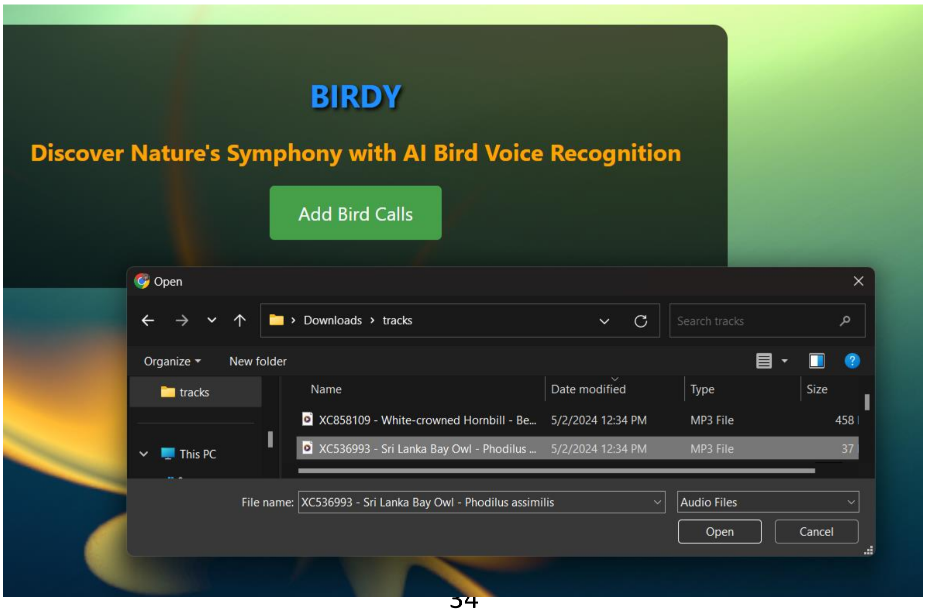
USER INPUT INTERFACE DESIGN

Users can communicate with the system by uploading audio recordings and entering the required data using the user input interface.

KEY FEATURES OF THE USER INTERFACE

- Users can upload recordings of their birdsong in the audio upload section.
- File Format Validation: ensures that only audio files in legitimate formats—like WAV—are recognized.
- Drag-and-drop functionality: This feature makes it simple to upload files by just dragging them into the appropriate location.
- Progress Indicator: Shows how far along the upload.





USER OUTPUT INTERFACE DESIGN

Users can comment on the submitted audio recordings by viewing the results of the bird sound detection procedure on the user output interface.

KEY FEATURES OF THE USER OUTPUT INTERFACE

- Display of Results: Based on the uploaded recording, this shows the anticipated species of bird.
- Confidence Score: Gives the prediction's probability or confidence score.
- Audio Playback: enables users to hear the sound segments that the algorithm has detected as well as the uploaded recording.
- Users can comment on the prediction's accuracy in the "Feedback" section.

06.01. TECHNOLOGY STACK

Frontend Technologies Framework: React.js to provide an easily navigable and responsive user experience for people to engage with the system.

HTML and CSS: To ensure a clear and user-friendly layout by organizing and decorating the web application.

JavaScript: For managing dynamic content on the front end and improving interactivity.

Python is the programming language for backend technologies.
Python is well-known for being straightforward and having a large library, making it perfect for jobs involving data processing and machine learning.

Web Framework: Flask uses Flask for features like user authentication in lightweight apps.

Database Technologies: PostgreSQL for database management systems
For relational data storage with sophisticated queries, use PostgreSQL; for unstructured data, such as audio files, use MongoDB for a flexible, schema-less solution.

Machine Learning Technologies Libraries: To create machine learning models that categorize and forecast bird sounds, use TensorFlow.

PyDub or Libra are two audio processing libraries that can be used to analyze audio signals and extract the features required for sound classification.

Collaboration and Version Control
Git is the version control system used to monitor codebase changes and facilitate developer cooperation.

06.02. DESIGN PATTERNS

Pattern of Strategy

Because the Strategy Pattern permits the variable use of several classification algorithms used to detect bird sounds, it is especially well-suited for the project aimed at predicting bird sounds. This makes it possible to create and train a variety of machine learning models on audio data, each with unique performance traits and adaptability to particular animals or sound kinds. The system can dynamically select which classification algorithm to utilize based on predetermined criteria, such as the properties of the recorded sound or user preferences, by encapsulating each algorithm within a separate strategy class.

This modular design not only makes it easier to maintain and improve the classification capabilities by enabling developers to add new models without changing the existing code, but it also enhances system performance by allowing strategies to be seamlessly switched between for best outcomes. As a result, the Strategy Pattern makes the system more flexible and resilient while managing a variety of audio categorization jobs, which makes it a great option for putting the project's main functionality into practice.

06.03. IMPLEMENTATION OF THE PROGRAM

The Bird Sounds Prediction Project's Implementation Process
The project setup phase of the bird sounds prediction project involves configuring the programming language environment, which is usually Python for backend development, and setting up an appropriate development environment, such as an IDE like Visual Studio Code.

After that, a fresh repository is created on a version control system such as GitHub in order to efficiently manage the project's codebase.

The next step in the frontend development process is choosing a framework to build the web application's responsive user interface, such React.js. A recording interface with start/stop buttons, a display area for displaying categorization findings, and data analysis visualizations like graphs and charts are among the UI components built during this phase.

Subsequently, the backend development stage concentrates on establishing a web framework such as Flask, which will manage backend functionality and handle frontend queries. To make it easier to upload audio recordings for processing, retrieve classification results, and handle user authentication, RESTful APIs are established.

Selecting a database is a necessary step in the database design process. PostgreSQL is one option for data storage. The Entity-Relationship Diagram (ERD) serves as the basis for the implementation of the database design, which includes tables for users, bird sounds, and recording sessions. An Object-Relational Mapping (ORM) tool such as SQLAlchemy for PostgreSQL is used to establish connections between the database and the backend.

Audio datasets of bird noises are gathered and preprocessed using libraries like Librosa to extract pertinent features throughout the machine learning model construction phase. After that, several machine learning models are created and trained using libraries like TensorFlow, including Random Forest and Convolutional Neural Networks (CNN). Metrics like accuracy, precision, and recall are used to assess the performance of the model, and any necessary fine-tuning is then made.

When audio recording capabilities is provided utilizing a backend library such as PyAudio or a frontend Web Audio API, integration of audio processing elements is crucial. The backend is linked to the learned models, enabling the real-time categorization of submitted audio recordings.

Unit tests are used to test individual components; frameworks such as PyTest for Python and Jest for JavaScript are used for this purpose. Integration testing makes ensuring that all of the system's parts function well together.

Docker is used to achieve containerization for deployment, contributing to the preservation of a consistent environment. When deploying the application, a cloud service like AWS, Heroku, or Google Cloud Platform is used to guarantee user accessibility.

Implementing monitoring technologies like Prometheus or Grafana to track application performance and health is the final step in the monitoring and maintenance process. The application is continuously updated with new features, bug repairs, and enhancements based on user needs and technical advancements. This allows for ongoing improvement as user feedback is received after deployment to identify areas for improvement and prospective feature additions.

07. TESTING & VALIDATION

07.01. TEST PLAN

Testing is an essential stage in the software development lifecycle that makes sure the criteria are met and the birds sound identification system operates as intended. The testing techniques used, such as functional testing, regression testing, integration testing, and unit testing, are described in this chapter. It also discusses the test cases and test strategy that are used to verify the system.

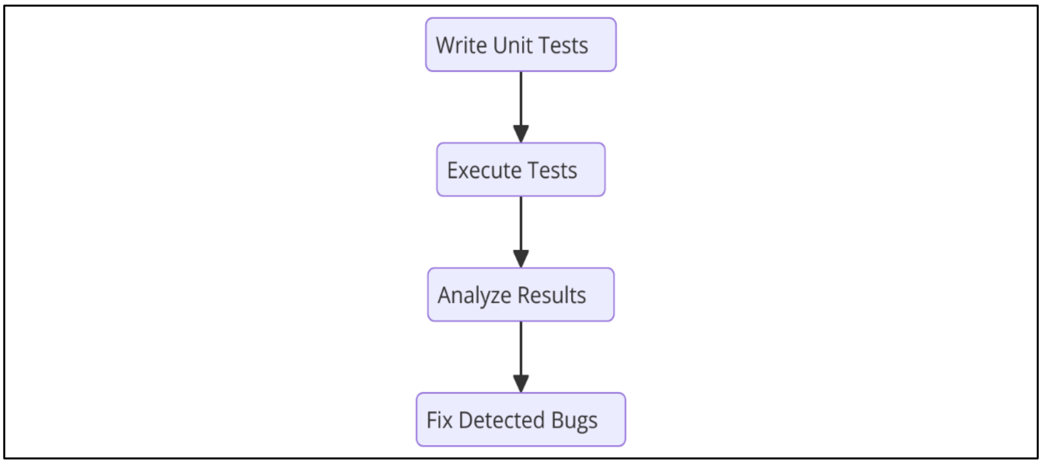
KEY OBJECTIVES IN TESTING

- Verify Functionality: Make sure the system's features all function as planned.
- Find Bugs: Find and address any problems or flaws in the system.
- Assure Quality: Verify that the system satisfies user requirements and quality standards.
- Validate Performance: Evaluate the system's dependability and performance in a range of scenarios.

07.02. TEST CASES

TEST STRATEGY – UNIT TESTING

Unit testing concentrates on testing distinct system parts or components separately. It seeks to guarantee that every unit operates properly on its own.



01. Test case; Test File Upload

Description; Systematic testing should be used to make sure the file upload feature functions as intended. Prior to using test files of different sizes and formats, such as audio files in WAV, MP3, or FLAC formats, a controlled environment must be set up. Using the frontend interface or third-party tools like Postman, the testing procedure starts by requesting these example files using the file upload API. Every upload attempt should be recorded, and the response from the server should be checked to make sure it provides a success status code (usually a 200 OK response). In order to verify accuracy, it is also necessary for the response body to include the intended file URL, which can be verified by cross-referencing it with the file storage location. To make sure the function functions as intended in a variety of circumstances, it is imperative to test multiple situations, such as successful uploads, uploads of file types that are not permitted, and uploads of files larger than the allowed size limit. It is important to check error messages for unsupported formats and size exceedances so that the user receives helpful and understandable feedback. In order to verify how the system responds to edge circumstances, such as uploading files with the same name or concurrent uploads, tests should be conducted. After every test is carried out, the findings should be recorded, emphasizing any inconsistencies and guaranteeing that the file upload feature reliably delivers the right file URL. This will validate the function's robustness and dependability for users in the future.

02. Test case; Bird sound prediction

Description; Testing the prediction method with a sample bird sound file URL is essential to confirming how well it works. To test the function, the first step in this process is to choose a well-annotated audio clip that is reputable for having distinct bird noises. Using the selected sample bird sound file URL as input, a request is sent to the application's prediction endpoint during the testing phase. The prediction function receives the request, processes the audio file, and extracts features that are necessary for classification, including spectrogram representations or Mel-frequency cepstral coefficients (MFCCs). A projected bird species and a confidence score showing the prediction's dependability should be the expected outputs. The projected species should be compared to the sample file's known species in order to verify the function's accuracy. This will allow you to evaluate the function's precision and accuracy. It is also useful to test the function with a range of bird sound files that represent various species and sound kinds, in order to examine how consistent the predictions are across a range of inputs. Any differences between the anticipated and actual outcomes must to be recorded, as this will reveal areas where the model needs to be improved. By using a thorough testing process, we can make sure that the prediction function is accurate, resilient, and able to produce consistent outcomes when used in real-world situations.

03. Test case; Test file upload and prediction endpoint

Description; A thorough testing procedure should be put in place to guarantee the functionality of the file upload and prediction endpoints in the project to predict bird noises. Testing the file upload endpoint is the first step. This entails choosing different sample audio files to represent different bird noises and using the application's frontend or a program like Postman to invoke the upload endpoint. It is important to confirm that every upload sends a successful response, usually in the form of a status code of 200 and a JSON object with the correct file URL for the audio file. This verification guarantees that the upload feature is operating as planned. The prediction endpoint needs to be tested when the file upload has been verified successfully. To evaluate the uploaded audio files, queries should be sent to the prediction endpoint using the file URLs that were obtained from the successful uploads. The prediction function should be activated with each request. It will then process the audio data and return a predicted bird species along with a confidence score. To evaluate the accuracy of the predictions, the predicted species should be compared to the known species found in the sample files. Conducting multiple tests with diverse audio samples can prove advantageous in assessing the coherence and dependability of the forecasts concerning diverse taxa and auditory categories. To make sure proper error handling is in place, it's crucial to confirm both endpoints' behaviors under various scenarios, such as uploading files that are larger than allowed or in an unsupported file type, in addition to confirming the right predictions. Every outcome should be carefully recorded, with any differences between anticipated and actual results noted. This thorough testing procedure will assist in verifying that the file upload and prediction endpoints operate accurately and dependably, guaranteeing a seamless user experience and precise bird sound classifications in the finished product.

08. Conclusion

The bird sound recognition project successfully achieved its goals of developing a functional and accurate system for identifying bird species from audio recordings. The project demonstrated the effective application of machine learning techniques and provided a user-friendly web interface for interacting with the system.

Despite some limitations, such as the size of the dataset and the impact of environmental noise, the project has laid a solid foundation for future improvements and enhancements. By addressing these limitations and incorporating user feedback, the system can continue to evolve and provide valuable insights to bird enthusiasts and researchers.

Overall, the project has been a valuable learning experience and has highlighted the importance of data quality, user experience, and thorough testing in the development of successful AI-driven applications.

08.01. FUTURE RECOMMENDATION

Subsequent improvements can concentrate on resolving the existing constraints and enhancing the system's functionality:

01. Extend Dataset: To increase model accuracy and generalization, gather and add a broader variety of bird sounds.
02. Enhance Noise Handling: Create algorithms that can differentiate between ambient noise and bird noises, as well as better handle background noise.
03. Optimize Performance: Use optimization strategies to speed up processing and increase the scalability of the system.
04. Include New Functionalities: Add more features like geographical mapping of bird sightings, real-time sound identification, or interaction with birdwatching communities.

08.02. LESSON LEARNED

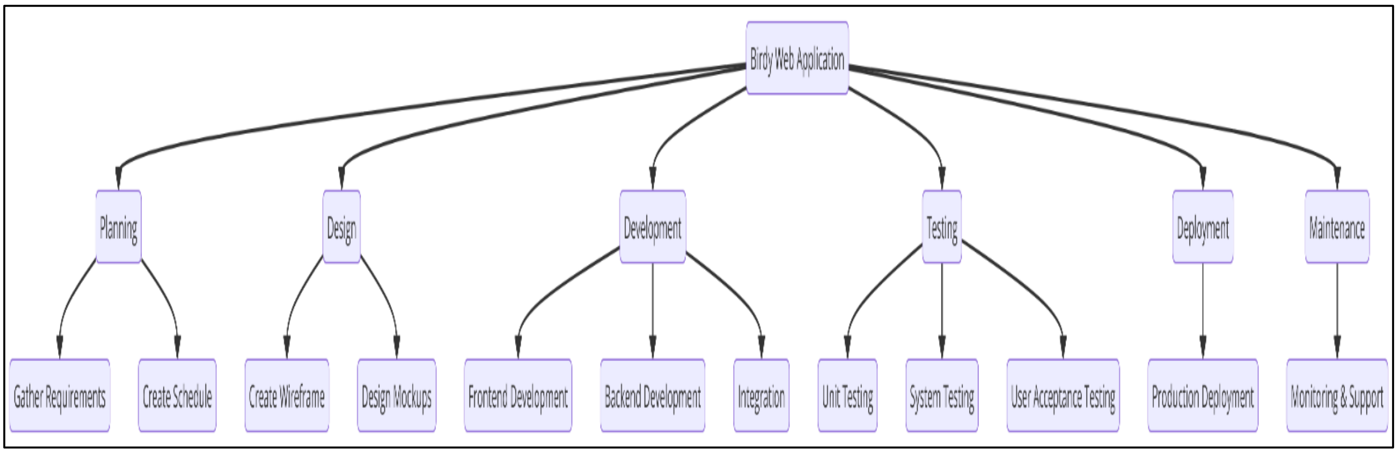
KEY LESSONS LEARNED

01. Importance of Data Quality: Accurate machine learning models require a large variety of high-quality training data. The performance of the model is directly impacted by the quantity and quality of the dataset.
02. User Experience Is Important The enjoyment and engagement of users are greatly increased by designing an interface that is easy to use. Recurrent user feedback is necessary for iterative enhancements.
03. Extensive Testing Is Required: Thorough testing in a range of scenarios aids in locating and resolving possible problems prior to deployment.
04. Adaptability: Long-term success and relevance are ensured by being ready to modify and improve the system in response to feedback and real-world usage.

RECOMMENDATION

01. Data Collection: To create a dataset that is more complete, make investments in data collection activities.
02. User Feedback: In order to make wise improvements, continuously collect and evaluate user feedback.
03. Ongoing Maintenance: To address problems and introduce new features, put in place a systematic maintenance plan.

GANTT CHART



Task	Due Date	Completion Date	Time Spent
Project Initiation	June 01–24	June 07–24	One Week
Requirement Analysis	08-Jun-24	21-Jun-24	Two weeks
System Design	22-Jun-24	05-Jul-24	Two weeks
Development:	June 6–July 24	26–July 24	Three weeks
Testing:	27–July 24	09– August24	Two weeks
The deployment period is as follows:	10-Aug-24	16-Aug-24	One week
Upkeep	17–24 August	Continual	Continual

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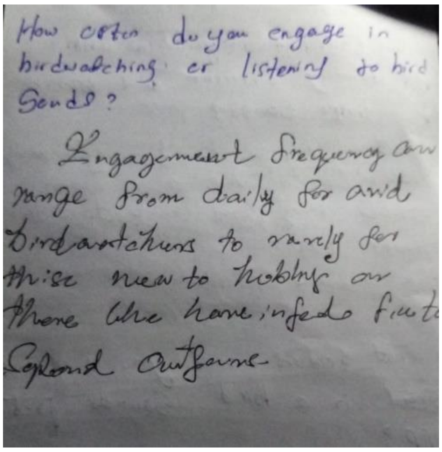
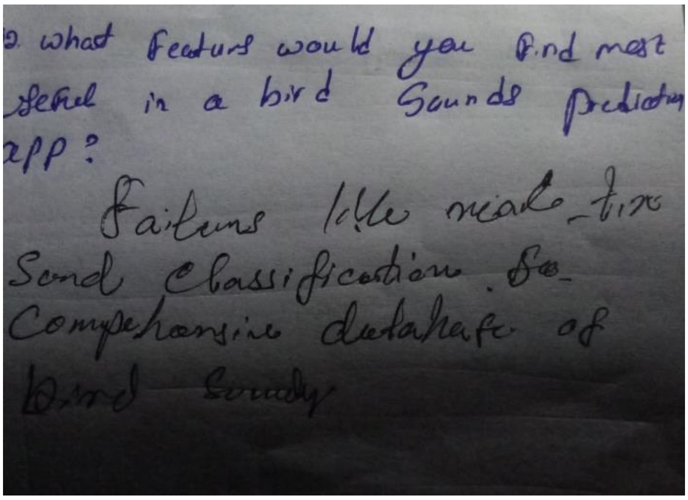
APPENDIX 01

QUESTION & ANSWERS



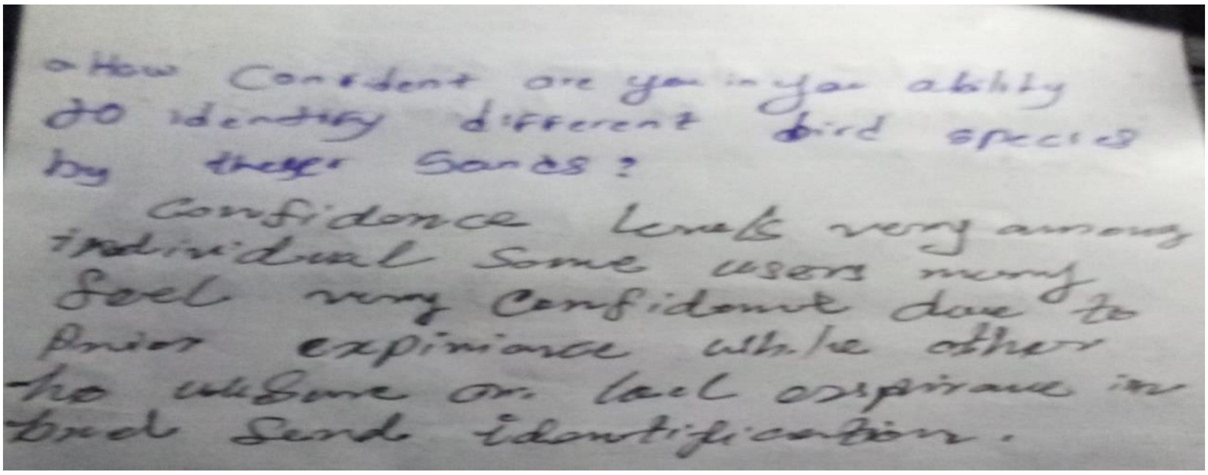
How often do you engage in birdwatching or listening to bird sounds?

Engagement frequency can range from daily for avid birdwatchers to rarely for those new to hobby or those who have infrequent explore outdoors.



2. What features would you find most useful in a bird sounds prediction app?

Features like real-time sound classification, a comprehensive database of bird sounds



3. How confident are you in your ability to identify different bird species by their sounds?

Confidence levels vary among individual. Some users may feel very confident due to prior experience while others may be unsure or lack experience in bird sound identification.

SOURCE CODE FOR TEST CASES

```python
import unittest
from your_module import predict_bird_sound

class TestBirdSoundPrediction(unittest.TestCase):
    def test_prediction(self):
        sample_sound = 'path/to/sample.wav'
        result = predict_bird_sound(sample_sound)
        self.assertEqual(result, 'Expected Bird Name')

if __name__ == '__main__':
    unittest.main()
```

```python
import pytest
from your_flask_app import app

@pytest.fixture
def client():
    with app.test_client() as client:
        yield client

def test_upload_and_predict(client):
    sample_sound = 'path/to/sample.wav'
    response = client.post('/upload', data={'file': (open(sample_sound, 'rb'), 'sample.wa
    assert response.status_code == 200
    assert b'Expected Bird Name' in response.data

if __name__ == '__main__':
    pytest.main()
```

```javascript
const { uploadSound } = require('./your_module');

test('uploadSound should return a file URL', () => {
    const file = new File([''], 'sample.wav', { type: 'audio/wav' });
    const url = uploadSound(file);
    expect(url).toMatch(/blob:http:\/\/localhost/);
});
```

```javascript
const { getPrediction } = require('./your_module');

test('getPrediction should return a bird name', async () => {
    const prediction = await getPrediction('blob:http://localhost/sample.wav');
    expect(prediction).toBe('Expected Bird Name');
});
```

```python
import pytest
from your_flask_app import app

@pytest.fixture
def client():
    with app.test_client() as client:
        yield client

def test_upload_and_predict(client):
    sample_sound = 'path/to/sample.wav'
    response = client.post('/upload', data={'file': (open(sample_sound, 'rb'), 'sample.wa
    assert response.status_code == 200
    assert b'Expected Bird Name' in response.data

if __name__ == '__main__':
    pytest.main()
```

APPENDIX 02

SUPERVISOR MEETING LOGSHEETS

Student's Name: Hansaka Nuwan Panagedara **Cardiff Number:** St 20967638 ICBT
Student Id Number: CL/BCSCD/25/180

Date: 26/08/2024 **Meeting No:** 01 **Intake:** September/2024

Project Title: Birdy (AI based birds Sound prediction web Application)

Supervisor's Name: Ms. Upeka wijesinghe **Signature:**

Assistant Program Manager: Miss. Kanchana Dilrukshi **Signature:**

Work progression as to date (noted by student BEFORE mandatory supervisor meeting):

Conducting research

Items for Discussion (noted by student BEORE mandatory supervisor meeting):

1. Background research
2. Recognition of research gap
3. problem Identification

Action List (to be attempted by student by the NEXT mandatory supervisory meeting – TO BE FILLED SUPERVISOR):

1. Explain documentation
2.
3.

Note: A student should make an appointment to meet his or her supervisor (via phone call or e-mail) at least 3 days prior to supervisory session. In the event a supervisor could not be booked for consultation, the Assistant Manager should be informed 2 days prior to supervisory meeting so that a meeting can be subsequently arranged.

Student's Name: Hansaka Nuwan Sithara Panagodage
Student Id Number: CL/BCSCOM/25/80 Cardiff Number: St20267833 ICBT

Date: 14/09/2024 Meeting No: 03 Intake: September/2024

Project Title: Birdy (AI based birds Sound predection wep Application)

Supervisor's Name: Ms. Upeka wijeshine Signature:

Assistant Program Manager: Miss. Kanchana Dilrukshi Signature……………

Work progression as to date (noted by student BEFORE mandatory supervisor meeting):

Completion of Chapter 04 & 05 & System

Items for Discussion (noted by student BEORE mandatory supervisor meeting):

1. Backend development
2. Frontend development
3. traning model

Action List (to be attempted by student by the NEXT mandatory supervisory meeting – TO BE FILLED SUPERVISOR):

1. ………… Check document
2. …………
3. ……………

Note: A student should make an appointment to meet his or her supervisor (via phone call or e-mail) at least 3 days prior to supervisory session. In the event a supervisor could not be booked for consultation, the Assistant Manager should be informed 2 days prior to supervisory meeting so that a meeting can be subsequently arranged.

Student's Name: Hansaka Nuwan Panagedara **Cardiff Number:** St 20967638 ICBT
Student Id Number: CL/BCSCD/25/180

Date: 26/09/2024 **Meeting No:** 01 **Intake:** September/2024

Project Title: Birdy (AI based birds Sound prediction web Application)

Supervisor's Name: Ms. Upeka wijesinghe **Signature:**

Assistant Program Manager: Miss. Kanchana Dilrukshi **Signature:**

Work progression as to date (noted by student BEFORE mandatory supervisor meeting):

Conducting research

Items for Discussion (noted by student BEORE mandatory supervisor meeting):

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