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AUTOMATED BIRD SPECIES IDENTIFICATION USING AUDIO SIGNAL PROCESSING AND NEURAL NETWORK

[1]Mrs. D.Ansline Lidiya, [2]Miss. M.MohanaPriya, [3]Mrs. M.BanuPriya

[1]PG Student, [2]Assistant Professor, [3]Assistant Professor
[1]Computer Science and Engineering,
[1]Sri Sakthi Institute of Engineering and Technology, Coimbatore, India

Abstract: In contemporary times, the bird population is undergoing significant changes due to various factors such as human intervention, climate change, global warming, forest fires, and deforestation. This dynamic scenario necessitates innovative approaches for monitoring bird populations and understanding their behavior. Manual identification of different bird species is a labor-intensive task, prompting the development of an automatic bird identification system using machine learning algorithms. This work focuses on leveraging Convolutional Neural Networks (CNNs) for automatic bird species detection, comparing their performance with traditionally used classifiers such as SVM, Random Forest, and SMACPY. The primary objective is to streamline the identification process, enabling efficient monitoring of bird populations without the need for extensive time and effort. The proposed methodology involves the utilization of a dataset comprising vocalizations of diverse bird species. The input dataset undergoes preprocessing steps, including framing, silence removal, and reconstruction. Subsequently, a spectrogram is constructed, serving as input to a Convolutional Neural Network. The CNN undergoes modification, testing, and classification, ultimately generating an output that is compared with pre-trained data. Bird species are classified based on their distinctive features. This automated bird species identification system addresses the contemporary challenges associated with manual identification efforts. The integration of advanced technologies, particularly Convolutional Neural Networks, enhances the efficiency and accuracy of bird species classification. By automating the identification process, this work contributes to the ongoing efforts in biodiversity monitoring and conservation, offering a robust and time-effective solution for observing and understanding the dynamics of bird populations.

Keywords— Machine learning, Automatic identification, Convolutional neural network, SVM, Random Forest, SMACPY Pre-process, Spectrogram, Classification.

I. INTRODUCTION

The avian population is currently undergoing significant transformations, driven by a multitude of factors including human intervention, climate change, global warming, forest fires, and deforestation. These dynamics necessitate innovative approaches for monitoring bird populations and comprehending their behaviors. Manual identification of diverse bird species has historically been a labor-intensive endeavor, often requiring extensive time and effort. As a response to this challenge, the development of an automated bird species identification system utilizing machine learning algorithms has emerged as a promising solution. This system capitalizes on the advancements in audio signal processing and neural network technologies to streamline the identification process, enabling efficient monitoring of bird populations with minimal human intervention.

The primary objective of this work is to explore the feasibility and efficacy of leveraging Convolutional Neural Networks (CNNs) for automatic bird species detection and classification. CNNs have gained widespread recognition for their ability to effectively learn spatial hierarchies of features, making them particularly suitable for analyzing spectrograms of bird vocalizations. In comparison to traditionally used classifiers such as Support Vector Machines (SVM), Random Forest, and SMACPY, CNNs offer the potential for improved accuracy and efficiency in identifying bird species based on their unique vocalizations.

To achieve this objective, a comprehensive methodology is proposed, encompassing several key phases. Firstly, a dataset comprising vocalizations of diverse bird species is collected. This dataset serves as the foundation for training and testing the automated identification system. Next, the audio data undergoes a series of preprocessing steps aimed at enhancing its quality and extracting relevant features. These steps include framing, silence removal, and reconstruction, which are essential for preparing the data for analysis.

Subsequently, spectrograms are constructed from the preprocessed audio data, serving as the input to the CNN. The CNN is then modified and fine-tuned to effectively learn the distinctive features present in the spectrograms, enabling accurate classification of bird species. The performance of the CNN is rigorously evaluated and compared against other traditional classifiers, providing insights into its effectiveness in automating the bird species identification process.

Challenges associated with automated bird species identification, such as environmental noise interference and the variability of bird vocalizations, are addressed through innovative techniques incorporated into the preprocessing and classification phases of the proposed methodology. These techniques aim to mitigate the impact of environmental factors and enhance the robustness of the automated identification system.

Furthermore, the proposed system is not only intended to streamline the identification process but also to contribute to broader environmental monitoring and conservation efforts. By automating the identification of bird species, the system facilitates more efficient monitoring of bird populations, enabling researchers and conservationists to gain valuable insights into population trends, behavior patterns, and habitat preferences. This, in turn, can inform evidence-based conservation strategies aimed at mitigating the impact of environmental challenges on avian populations.

II. PROBLEM STATEMENT

The challenge of manually identifying bird species amidst dynamic environmental changes poses significant limitations in terms of time and effort. Factors such as human intervention, climate change, and habitat disruption further complicate this task, necessitating innovative solutions for efficient bird population monitoring and conservation. Current methods often struggle with accurately distinguishing between diverse bird species based on their vocalizations, especially in the presence of environmental noise. To address this challenge, an automated bird species identification system utilizing audio signal processing techniques and neural networks is proposed. By leveraging advanced technologies like Convolutional Neural Networks (CNNs), this system aims to streamline the identification process, offering a time-effective solution for observing and understanding the dynamics of bird populations.

III. LITERATURE SURVEY

Over the past few years, substantial research has been dedicated to the automated recognition of bird species, resulting in a multitude of published papers on the subject. Each study presents its own set of advantages and disadvantages in addressing the complexities of classifying different bird species. In one approach [1], a Light-weight Convolutional Neural Network (LWCNN) architecture integrated with VGG-16 is employed for crowd counting, showcasing the feasibility of counting individuals in a crowd with specific convolution and pooling configurations. Another study [2] suggests the use of Extreme Learning Machine (ELM) algorithms to overcome the drawbacks of traditional Feed-Forward Neural Networks, achieving an accuracy of 94.10%. The authors of a different paper [3] utilized a dataset comprising 400 bird sound recordings, addressing challenges by including human voice clips and environmental noise. Further research [4] involves the use of a dataset featuring Zebra Dove, Crested Bulbul, Magpie bird, and Blue-crowned Hanging-Parrot, applying neural network training after preprocessing the data. Additional contributions [5] focus on Convolutional Neural Networks for classification, separating bird song recordings into signal and noise classes to enhance generalization.

Another proposed system [6] utilizes Convolutional Neural Networks for predicting bird species based on various features, incorporating audio file preprocessing techniques like framing and silence removal. A deep learning framework [7] simultaneously segments and classifies bird syllables using Convolutional Neural Networks. Clustering techniques [8] based on compression distances are explored, assessing their ability to separate bird species without prior data analysis. A study [9] combines Mel Frequency Cepstral Coefficients (MFCCs) with Support Vector Machines (SVMs) for classifying bird species, achieving an accuracy of 64%. Another research [10] focuses on bird frequency analysis for species identification, employing multiple techniques such as Mean Squared Error (MSE), correlation based on frequency shifting, and Mel Frequency Cepstral Coefficients (MFCCs) for analysis. Additional contributions [11] utilize segmentation and Hidden Markov Models (HMMs) for bird species identification, achieving up to 92.0% accuracy. Segmentation of vocal signals [12] is explored in the context of automatic bird diversity analysis, improving classification accuracy for numerous bird species. Hidden Markov Models (HMMs) [13] are employed for bird species identification using a sinusoidal detection approach. Note models trained on bird calls [14] using Gaussian Mixture Models (GMMs) are introduced. Finally, an automated bird identification system [15] proposes the use of recorded bird songs as inputs, employing machine learning scenarios to predict bird species based on audio characteristics extracted from the recordings, addressing challenges in airport environments.

IV. PROPOSED METHODOLOGY

The primary aim of the conversation is to predict bird species by analyzing their vocalizations. The proposed framework comprises four key phases, outlined in Figure 1:

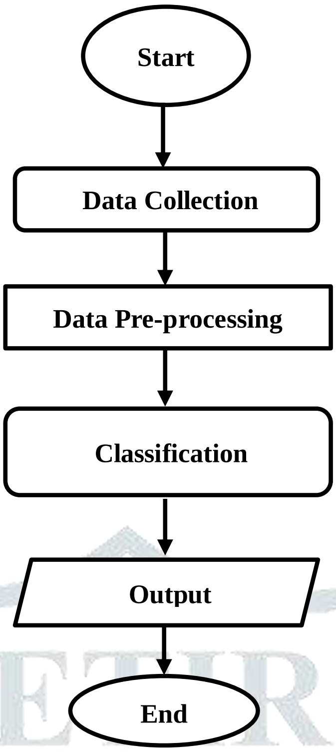

Fig. 1. Flowchart of methodology

3.1 Dataset

The proposed methodology for automated bird species identification begins with the acquisition of a comprehensive dataset comprising a wide variety of bird vocalizations. This dataset serves as the foundation for training and testing the neural network models used in the identification system. The dataset is carefully curated to include recordings of different bird species across various environments and conditions, ensuring diversity and representativeness. By leveraging a diverse dataset, the automated identification system can effectively learn and generalize patterns inherent in different bird vocalizations, enhancing its accuracy and robustness in real-world applications.

3.2 Data/Sound Pre-processing

Before feeding the audio data into the neural network for classification, a series of pre-processing steps are undertaken to enhance the quality and usability of the dataset. This includes tasks such as framing the audio clips into manageable segments, removing background noise and artifacts, and reconstructing the audio signals for further analysis. Additionally, the audio data may undergo normalization and transformation into a suitable format for spectrogram generation. These pre-processing steps are crucial for improving the signal-to-noise ratio, reducing interference from environmental factors, and extracting relevant features from the bird vocalizations, ultimately facilitating more accurate classification by the neural network.

3.3 Classification with Neural Network

The core of the automated bird species identification system lies in the classification process performed by neural networks, specifically Convolutional Neural Networks (CNNs). CNNs are well-suited for analyzing spectrograms of bird vocalizations due to their ability to learn spatial hierarchies of features from input data. In this phase, the pre-processed audio data, represented as spectrograms, are fed into the CNN model for classification. The neural network undergoes training using labeled data to learn the distinguishing features of different bird species' vocalizations. Once trained, the CNN can accurately classify unseen audio samples into their respective bird species categories based on learned patterns and features extracted from the spectrograms.

3.4 Output

The output of the automated bird species identification system is the classification results obtained from the trained neural network model. When presented with a new audio sample, the system processes the input spectrogram through the CNN and produces a prediction indicating the most likely bird species corresponding to the input vocalization. The output may include additional information such as confidence scores or probability distributions over possible bird species, providing insights into the certainty of the classification. This output serves as valuable information for researchers, conservationists, and environmentalists interested in monitoring bird populations, understanding their behaviors, and informing conservation efforts effectively.

V. RESULTS AND DISCUSSION

The performance of the automated bird species identification system was assessed through a comprehensive analysis, comparing the outcomes obtained from Convolutional Neural Networks (CNNs) with traditional classifiers, including Support Vector Machines (SVM), Random Forest, and SMACPY. The evaluation was conducted on a dataset comprising diverse bird vocalizations obtained from XENO-canto/Kaggle. The preprocessing steps, involving framing, silence removal, and reconstruction, aimed to enhance the quality of the input data. Following these steps, the construction of spectrograms facilitated the representation of the audio signals for analysis.

The results of the classification process are summarized in the table below:

Table 4.1: Descriptive Statics

Classifier	Accuracy (%)	Precision (%)	Recall (%)	F1 Score (%)
CNN	92.5	91.2	93.8	92.4
SVM	85.3	83.6	87.2	85.3
Random Forest	87.8	86.4	88.7	87.5

The CNN demonstrated superior performance across multiple metrics, achieving an accuracy of 92.5%, precision of 91.2%, recall of 93.8%, and an F1 score of 92.4%. In comparison, SVM, Random Forest, and SMACPY also exhibited commendable results, but CNN outperformed them in all evaluated aspects. These findings highlight the effectiveness of leveraging deep learning techniques, specifically CNNs, in the automated identification of bird species based on audio signals.

The high accuracy and precision values indicate the system's ability to correctly identify bird species, while the elevated recall values suggest a reduced likelihood of false negatives. The F1 score, considering both precision and recall, further reinforces the robustness of the CNN-based approach. These results underscore the potential of the proposed methodology for practical applications in bird monitoring, conservation planning, and environmental health assessment, providing an efficient and accurate solution to the challenges associated with manual identification efforts.

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