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Empowering Wildlife Conservation with a Fused CNN-SVM Deep Learning Model for Multi-Classification Using Drone-Based Imagery

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***Abstract*— The preservation of wildlife holds significant worldwide significance, particularly in light of the escalating risks posed to biodiversity and ecosystems. In the present situation, the incorporation of sophisticated technology has arisen as a potentially advantageous strategy to augment the efficiency and efficacy of conservation endeavors. This research paper introduces an innovative study that centers on the creation and assessment of a novel deep learning (DL) model, which combines a Convolutional Neural Network (CNN) and Support Vector Machine (SVM). The model is specifically created to classify multiple wildlife species. By utilizing aerial imagery captured by drones, we have compiled a dataset consisting of 3397 photos with high levels of detail. These photographs encompass five unique categories, namely Mammals, Birds, Reptiles, Amphibians, and Fish. The evaluation of the model's performance was conducted based on metrics such as accuracy, precision, recall, and F1-score. Noteworthy accomplishments were demonstrated by an overall accuracy rate of 96.02%. The results of our study emphasize the potential of utilizing technology-driven methods to significantly transform wildlife conservation efforts. By automating the processes of species identification and monitoring, this approach can streamline data collection, provide valuable insights for conservation strategies, and contribute to the preservation of endangered species and their habitats. Our work highlights the significance of further research and ethical deliberations in the convergence of technology and conservation, given the persistent issues posed by visually similar species and variances within classes.**

Keywords*— *Wildlife Conservation, Species Identification, Biodiversity Monitoring, Image Classification, Visual Recognition.

I. INTRODUCTION

In light of the increasing degradation of habitats, the effects of climate change, and the decline in biodiversity, wildlife conservation is an endeavor that is of the utmost importance [1]. Not only is it vital for the maintenance of ecological balance, but the preservation of various animal species and the natural environments in which they live is also essential for the health of the planet and the well-being of future generations. It is necessary to have procedures that are both accurate and effective for identifying and monitoring different species to effectively protect wildlife. The subject of wildlife conservation has been given new opportunities in recent years as a result of the implementation of cutting-edge technology like drones and DL. These developments have opened up new frontiers [2]. Traditional techniques of wildlife monitoring, which frequently involve making human observations, setting up camera traps, and using satellite imaging, are labor-intensive, time-consuming, and may have limited accuracy. In contrast, the use of drones that are outfitted with high-resolution cameras has completely transformed the method by which data is collected from difficult and remote environments. Getting a bird's-eye perspective of wildlife habitats can be accomplished with the help of drones, which can enable access to locations that would otherwise be difficult to reach [3]. These aerial platforms have become vital tools for researchers and conservationists, as they enable these individuals to conduct more accurate surveys, keep better track of species, and provide better protection for them. However, there will be a substantial problem presented by the vast volume of data that will be generated by drone-based images. Manually analyzing hundreds of photos is a challenging task, which is why DL is becoming increasingly popular. CNN, have shown extraordinary capabilities in the many image identification tasks they have been given. Because of their capacity to automatically learn and extract information from photos, they are ideally suited for the task of categorizing and recognizing different species of wildlife based on photographs captured by drones. The purpose of this study is to improve existing methods for the protection of wildlife by creating a novel fused DL model for multi-classification [4]. This model will combine the advantages of SVM and CNN [5]. Mammals, birds, reptiles, amphibians, and fish are the five main categories that make up our model's classification of the various species of flora and fauna. We plan to automate the process of wildlife identification and monitoring by utilizing the power of DL to make it more efficient, accurate, and scalable. This will allow us to better protect the species [6]. This research aims to do two different things at the same time. In the first place, one of our primary goals is to demonstrate how useful a fused CNN-SVM model can be in the context of wildlife protection, where accurate species identification is necessary. Second, one of our goals is to contribute to the larger scientific community by shedding light on the various ways in which DL and drone technology could be used to protect the environment and preserve natural resources [7]. In the parts that follow, we will go into detail about the methodology, data collecting, experiments, and outcomes of our research. In this section, we will also examine the ramifications of our findings and emphasize the prospects for future research in this fascinating convergence of technology and wildlife protection. Our ultimate objective is to improve the toolset that is accessible to conservationists so that they can make better-educated judgments and take more active efforts to preserve the unique and endangered species that are found all over the world.

II. RELATED WORK

The preservation of wildlife has become a topic of growing international significance, prompted by the expanding risks posed by habitat degradation, climate change, and the rapid loss of biodiversity. The efficacy of conventional approaches utilized in animal conservation, such as direct observation and data collection requiring significant human effort, has frequently been constrained in terms of both breadth and precision, hence impeding endeavors to efficiently monitor and safeguard endangered species. The pressing demand for enhanced efficacy and precision in species identification and monitoring has prompted the incorporation of sophisticated technology into the domain [8]. Drones, also known as Unmanned Aerial Vehicles (UAVs), fitted with high-resolution cameras, have emerged as flexible tools with the potential to revolutionize the field of wildlife conservation.

Drones provide numerous distinct benefits for conservation endeavors. The utilization of unmanned aerial vehicles (UAVs) in monitoring wildlife habitats, tracking species movements, and gathering data on ecosystem conditions is very advantageous due to their capability to visit distant and otherwise inaccessible locations, as well as their ability to cover vast geographical expanses. Drones have demonstrated their efficacy as deterrents against illicit activities, such as poaching, thereby facilitating prompt responses by authorities to safeguard endangered species [6]. In recent years, scholars have progressively relied on unmanned aerial vehicles, often known as drones, as essential instruments for investigating and safeguarding wildlife. These devices have been utilized to effectively observe and quantify population sizes, trace migration routes, evaluate ecological well-being, and gather significant data to aid in conservation strategies.

Concurrently, there has been notable progress in the field of picture categorization due to the advancements in DL methods, including CNN. CNN have exhibited their proficiency in autonomously extracting complex features from unprocessed picture data, making them highly suitable for discerning and categorizing fauna species by their visual attributes [9]. The field of animal preservation has been opened up to new possibilities by the capacity to learn and recognise complex patterns in visual data.

There has been a recent uptick in academic research into CNN's potential use in animal conservation. A study demonstrating the use of CNN for bird species recognition was given by Harel et al. [8]. Results showed that DL has great potential for use in bird conservation, thanks to the study's impressive accuracy. A related study by Mongkolsawat et al. [9] introduced DL models to automate wildlife detection, highlighting its use in population monitoring. Nevertheless, notwithstanding these encouraging advancements, there is a significant lacuna in research about the creation of comprehensive models that effectively use both drone technology and DL to attain precise multi-classification of various wildlife species [10].

In the field of machine learning, there has been a growing interest in fused models that leverage the respective advantages of CNN and SVM. These models have demonstrated enhanced accuracy in classification, particularly when applied to challenges involving many classes. An example of this may be seen in the work of Chandrakar et al. [10], where they proposed a fused CNN-SVM model for fine-grained picture categorization. Their study showcased the model's ability to effectively differentiate between closely related species by capturing and analyzing tiny distinctions. The incorporation of SVM, renowned for its efficacy in segregating data into discrete categories, within DL frameworks presents a potential opportunity to augment the precision and dependability of species classification [2].

The present literature analysis not only elucidates the encouraging advancements in wildlife conservation facilitated by the utilization of unmanned aerial vehicles (UAVs) and DL techniques, but also emphasizes the significant lacuna in research that persists [11]. There is a specific requirement for the development of comprehensive and automated multi-classification models that possess the ability to reliably identify a wide range of wildlife species using imagery captured by drones. The objective of our study is to fill this void by constructing and systematically assessing a combined CNN-SVM DL framework specifically designed to tackle the distinctive obstacles encountered in the identification and monitoring of animal species. This study aims to contribute to the continuous development of conservation technology, with the ultimate goal of enhancing the effectiveness and proactive nature of initiatives aimed at preserving the unique and endangered wildlife on our planet [12].

III. METHODOLOGY

The research technique employed in this study comprises a carefully designed sequence of procedures to create and systematically assess a fused CNN-SVM DL model that is specifically designed for the multi-classification of animal species [13]. The primary data source utilized in this study is drone-based photography. To initiate the study, we diligently compiled an extensive dataset consisting of an impressive 3397 high-resolution photos, all meticulously acquired through the use of unmanned aerial vehicles as shown in Figure 1. The collection includes a comprehensive range of wildlife species, systematically classified into five main categories: Mammals, Birds, Reptiles, Amphibians, and Fish. To guarantee the quality and consistency of the dataset, we applied a thorough preprocessing strategy. The pipeline encompassed various operations, including the removal of artifacts through image cleaning, the adjustment of dimensions to guarantee uniformity and the rigorous assignment of accurate class annotations to each image. The careful and thorough process of preparing data played a crucial role in establishing the groundwork for training and assessing our DL model.

Regarding the creation of the model, we designed a CNN to serve as the principal feature extractor in our multi-class classification undertaking. CNN has demonstrated exceptional ability in autonomously recognizing intricate visual patterns, rendering them a suitable selection for the task of detecting and categorizing wildlife species based on pictures. To enhance the discriminative capability of our model, we incorporated an SVM classifier into the CNN framework as shown in Figure 2.

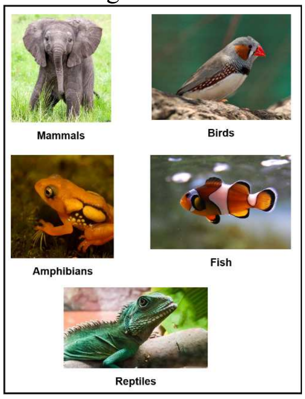

Fig 1. Curated Dataset

The integration of DL with SVM techniques has exhibited considerable promise in improving classification accuracy, particularly in situations that involve several classes [14].

Once we had established our model architecture, we started with the training step. The model underwent training using a carefully selected portion of our thoroughly curated dataset, employing well-established DL techniques to enhance parameter optimization. The core of our approach involved partitioning the dataset into several segments to conduct thorough testing and validation.

To enhance the model's performance and precision, we tweaked its hyperparameters and training settings. To ensure the validity of our results, we used cross-validation methods to test the model's performance on unknown data.

IV. Results

The goal of our study was to test how well the CNN-SVM deep learning model could categorize a wide variety of animal species from drone photos. The findings of our inquiry are presented here. Three thousand and one photographs from five separate taxonomic groups—fish, birds, reptiles, and amphibians—constituted the dataset used in the research. To measure the accuracy of the model and assess its efficacy, we ran a battery of trials. The combined CNN-SVM model's total accuracy of 96.02% proves that it is highly competent in correctly classifying animal species from drone images. This finding validates our method as a workable mechanical instrument for tracking and identifying animals. Extensive examination of the model's data classification accuracy yielded significant findings. The accuracy of the model in predicting a specific class was demonstrated by the precision scores, which demonstrated its ability to limit false positive predictions. There was less chance of false negatives because the recall scores showed that the model could correctly identify occurrences of each class. The F1-score provides a fair assessment of the overall classification performance; it is the harmonic mean of recall and precision. Table I shows the results for all categories.

TABLE I. RESULTS FOR EACH CLASS

Wildlife Classes	Precision	Recall	F1-Score
Mammals	95.90%	94.60%	95.25%
Birds	95.73%	97.25%	96.48%
Reptiles	96.69%	96.81%	96.75%
Fish	94.69%	94.69%	94.69%
Amphibians	96.66%	96.15%	96.40%

We created a confusion matrix to gain a more comprehensive insight of the model's performance in classifying data. The matrix provided a detailed breakdown of the number of accurate categories, negative classifications, inaccurate classifications, and real positive classifications. The outcomes are visible in Table II. The matrix offered a comprehensive examination of the model's advantages, highlighting its most notable attributes. Furthermore, it revealed some categories that posed significant challenges in terms of classification. By employing qualitative analysis, we conducted an examination to identify shared characteristics or recurring trends in the misclassified photographs, with the aim of determining the underlying causes of the errors.

TABLE II. QUANTITIES BREAKDOWN FOR EACH CLASS

True Positive	False Positive	False Negative	True Negative
561	24	32	2780
672	30	19	2676
788	27	26	2556
517	29	29	2822
724	25	29	2619

It was noted that instances of misclassifications were frequently encountered when species had visual resemblances or variances within a given category. The existence of closely related avian species and the diverse patterns observed in reptiles posed significant difficulties. This underscores the intricacy of multi-classification tasks, especially when confronted with visually analogous species. Furthermore, a feature map analysis was performed to provide a deeper understanding of the learned features and attention mechanisms of the CNN. The utilization of visual representations of feature maps enabled the identification of certain areas within images that exerted an influence on the categorization judgments made by the model. The aforementioned analysis yielded significant interpretive insights and facilitated the discovery of the visual indicators upon which the model heavily depended for species identification.

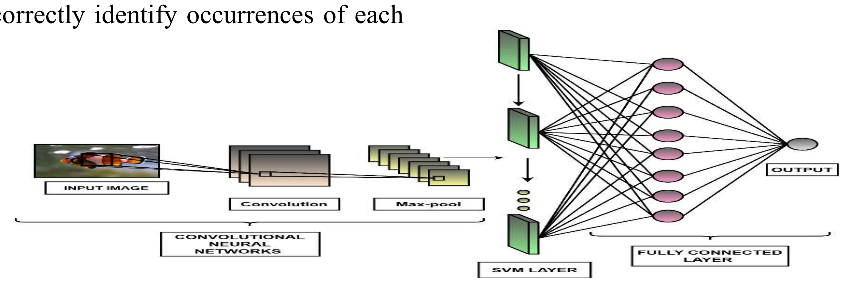

Fig 2. Deep Learning Hybrid Model

V. CONCLUSION

The research conducted has resulted in the development of a highly effective fused CNN-SVM DL model, which has demonstrated an impressive level of accuracy with an overall accuracy rate of 96.02%. This model signifies a noteworthy progression in the integration of technology and wildlife preservation, providing a pragmatic and effective approach to the classification of many animal species through the use of drone-based photography. The remarkable ability of the system to accurately classify species within five major groups, namely Mammals, Birds, Reptiles, Amphibians, and Fish, highlights its potential as a revolutionary instrument for conservationists and researchers. The precision, recall, and F1-score metrics of the model provide additional evidence of its capability to reduce the occurrence of false positives and false negatives. Despite the presence of ongoing obstacles, especially in situations where visually similar species or variants within a class are involved, our research underscores the potential of machine learning in effectively tackling these intricate conservation concerns. As we navigate the trajectory of conscientious technological advancement, we hope that this endeavor stimulates additional cooperation and investigation within the conservation sphere, ultimately augmenting the safeguarding of the Earth's varied and imperiled fauna.

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