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Dragonfly-Net: Dragonfly Classification using Convolution Neural Network

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Abstract: Scientific and engineering interests towards dragonflies has been a consistent source of ideas and solutions owing to the evolutionary success of the species. The importance of these ”toothed ones”, as the Greek translation of the family name ”Odonates” maps to, in terms of ecological diversity is invaluable, more pressingly with the context of only two of the six suborders of the order Odonata being non-extinct. With a wide spread existential timeline, identifying them is in itself is a critical task for taxonomists. This literature is oriented to provide a standard identification tool that aids researchers, amateur naturalists, and beginners in quick and easy identification of odonates, thus aiming to influence deeper exploration of the order. We propose a novel approach in terms of Dragonfly-Net, that has a widespread application possibility in the field of ecology and biology, starting with classification of a given image with dragonfly or dam-selfly into the pre-trained list of species belonging to the order, without any pre-processing. The proposed model performed with an accuracy of 76.99% on the training set, 67.59% on the validation set, and 61.35% on the hold-out set. The model predicts 94 different species of drag-onflies/damselflies. The effort is also protruded to derive and investigate the performance of the model with state-of-the-art evaluation techniques, scoped to explore the regions of activation contributing to its performance.

Keywords: Convolution neural networks, Deep learning, Dragonflies, Insect identification, Odonates.

I. Introduction

Intersection between technology and ecology has been clustered around specific sectors of living organisms, which coordinate for the benefit of humans in a direct or indirect mechanism. Insecta being one of the most diverse phyla in the animal kingdom, has been both a friend a foe to humans. Very commonly, identification of insects for humans has intuitively been through the vivid visual cues the former present. Although, some interesting efforts such as [7] and [1] utilise acoustic context to identify the insects. While audio signals have been popularly used to even identify birds [3], automated classification of species has been the problem statement of interest across efforts, with significant emphasis on computer vision. Early efforts along the pursuit have evolved from manual analysis of processed images [13] to usage of statistical methods such as PCA and semi-automatic analysis systems [11]. Later advancements towards selective feature extraction and classification, involving classifiers such as SVMs and ANNs, have been followed by automated feature extraction and classification, predominantly with the dawn of Convolutional Neural Networks. One of the early milestones in the pursuit involves feature extraction using techniques of PCA [12], wherein the authors attempt

Odonates, especially dragonflies and damselflies, are beautiful and attractive creatures with colorful patterns on wings and abdomen. Their lifestyle is more colorful than they are. Their life starts in the water and ends in the air. The larvae live in water, and they hunt insects and small fishes. Their history falls back to the Carboniferous era. They are primarily aquatic animals making them a great indicator of wetland health. Even with the importance, their documentation and distribution are poorly known.

Dragonflies biologically belong to the kingdom Animalia, phylum Arthropoda, class Insecta, order Odonata. There are three major super-families Aeshnoidea, Cordulegastroidea, and Libelluloidea. Aeshnoidea contains four families hawkers or darners, clubtails, petaltails, and Austropetaliidae. Cordulegastroidea has Chlorogomphidae, Cordulegastridae, and Neopeataliidae families, and Libelluloidea has Corduliidae, Libellulidae, Macromiidae, Synthemistidae families. There are 5860 known species are belonging to these families. Fossils of dragonfly ancestors from 325 million years shows a wingspan of 750 mm. The decrease in wingspan and size is due to the reduction in oxygen concentration in the atmosphere. More than 3000 species are extinct due to the loss of wet-grasslands around the world. Dragonflies are some of the most prominent predators in an aquatic habitat, feeding on insect eggs and larvae. Dragonfly nymphs and adults are also predators. In the insect food chain, they play a substantial role.

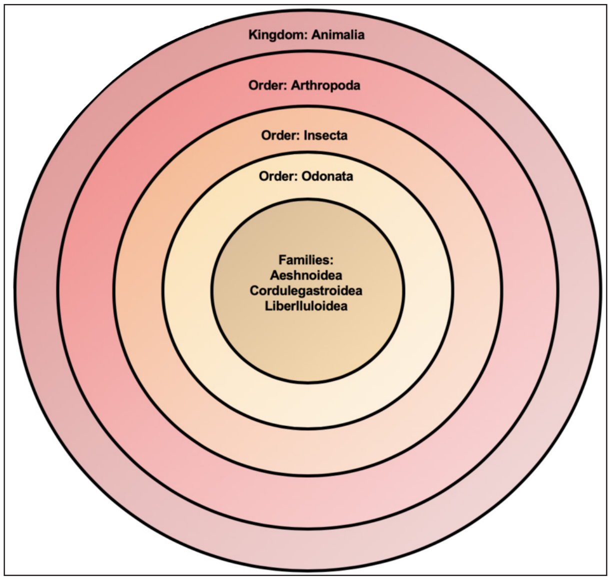

Fig. 1: Technique Frequency in the Explored Literature

They have a considerable significance for humans as well as ecology. Dragonflies are predators; they naturally feed on mosquitoes and other insects. They majorly control Aedes Mosquitoes, which cause dengue fever. They play a considerable role in pest control for crops and are considered farmers friends. They act as biological indicators. Since they are predators, the number of dragonfly species near industrial is larger than undisturbed environments. This shows that the prey for them is abundantly available. Many organisms indicate variation in nature; they are referred to as ecological indicators. Dragonflies suggest a high amount of pollution, metallic elements in air [10]. They are proven to show the pollution in water bodies as they spend their early life in water. Some dragonflies show up in a large number indicating air pollution. Many traditions believed they mean rain, draught, and prosperity to the livelihood of the community.

The Naive method of identifying and classifying dragonflies involves several taxonomic challenges. High-level classification of these insects involves several complex procedures.

Dragonflies are excellent at their flight. They can fly forward and backward as well. They are some of the fastest and can reach speed up to 25 to 30 kmph and turn 180 degrees in their flight [10]. They have also inspired designs of modern supercars, and their eyes inspired high definition cameras.

The evolution of bio mimicking can boost the advancement in technology along with the conservation of the species. Easy identification can lead to a better understanding of the behavior, life cycle, and habitat to the next level.

II. Motivation

Insects are the largest group of insects in the *Phylum Arthropoda*. Insects play a crucial role in the food chain. Odonates, especially dragonflies, acquire the top position in it. They are ferocious predators and cannibalize the same species.

If any actor in the food chain gets eliminated, the whole food chain disrupts. It is essential to conduct research activities and understand the species to conserve them and learn from them.

Biomimicry, a branch of study, deals with mimicking other creatures to improve the technology and betterment of humankind. As we mentioned earlier, dragonflies inspired the design of supercars and HD cameras. More research can show light to solve the problem of communication, transportation, and global warming.

There are mobile applications available to identify butterfly species as well as to identify frogs. But there are no such applications that can detect odonates.

Considering all these, we propose our research work to boost the field's research activities and conserve dragonflies.

This work can help build a standard identification tool that aids researchers, amateur naturalists, and beginners to quickly identify odonates.

III. Related Work

Identification and classification of these insects are difficult due to the high degree of similarities among different species. The decreasing number of taxonomists is also a major setback in studying these species. As per the survey [12], image-based identification is much lesser in usage. The solution to all these is a deep learning-based platform that can identify species based on the images.

Our previous work, a survey on image-based insect identification [5], discussed the previous works done in the field, and we found that there is no existing work done in the area of image-based automatic dragonflies identification. Previous works are majorly concentrated on identifying pests such as wasps, wild bees, and butterfly species.

IV. Dataset

Unlike any other deep learning tasks, data collection and annotation was a major challenge. We crawled the web to get the required data; thanks to Python and Selenium tool, we collected 7591 images of 94 dragonfly species. The images acquired were of different sizes. The whole dataset is resized into 249x200, keeping the aspect ratio unchanged.

The individuals in the dataset belong to 3 prominent families, Aeshnoidea, Cordulegastroidea, and Libelluloidea. Individuals are predominantly classified based on colors, wing patterns, and habitat.

The major obstacle, the annotation, was done by grouping the same species in a separate directory.

The quality of the dataset was determined using cluster analysis. We used density-based cluster analysis, DBSCAN [2] for it. The dataset features are extracted using the VGG network, and these features are clustered using DBSCAN. The F-score, the weighted harmonic mean of precision and recall, was estimated at 0.7664

$$F\ Score = \frac{2\ .\ precision\ .\ recall}{precision + recall} \quad (1)$$

Cluster purity is a criterion to determine the available data's clusterability, which is explained as the average of maximum clusterable point and true cluster.

$$ClusterPurity = \frac{1}{n\ clusters}\sum_{n=1}^{k} \max|\text{sample} \cap \text{test}| \quad (2)$$

The DBSCAN clustering of the image dataset provide cluster purity of 0.7443.

V. Methodology

The dataset, a collection of seven thousand and odd images, is categorized into different directories, which are used for annotation during training. The images are resized and compressed to reduce the overhead during training.

The image given as input should be classified to one of the 94 predefined classes. The process of classification/identification involves the following steps:

- image input (128x128)
- feature extraction using dragonfly-net
- classification/identification.

The images of size 128x128 are vectored to 40000 individual units. This was given as input, which goes through many filters of order 7x7, 5x5 in the later layers. These are discussed in the interpretation section later in the paper.

The main reason being lack of data. To overcome that problem, we used regularisation techniques and tuned the model to learn appropriately without overfitting.

Architecture Design

Dragonfly-net, a custom neural network inspired by residual networks [4], incorporates skip connection for every three layers. The skip connections help to overcome the problem of feature loss and vanishing gradients. However, the work involved learning more complex features and patterns. The skip connections help to recognize more complex patterns than a sequential network.

Dragonfly-Net: Architecture

The proposed network has 52-layer architecture. The first layer is a 7x7 convolution layer, which is followed by a 3x3 max-pooling. The architecture follows shorting the output of the layers. The output of the max-pooling layer is combined with output of the unit. A 1x1 convolution, followed by a 3x3 convolution followed by another 1x1 convolution layer, forms a unit. After the first three units, the feature map will be halved, and the number of filters will be doubled. This helps prevent the network from falling into the vanishing gradient situation, reduces the number of feature maps, and fastens the training process.

During training, the learning rate was adjusted according to observed high steepness in changing loss, and minimum loss [8] and the model was trained using cycle policy [9] the model was prone to overfit during training, The reduced feature map from the bottleneck is passed on to many sequential layers, followed by many bottleneck layers. A fully connected layer with adaptive average pooling activation transforms the features, and these features are passed to the next layer. Finally, the Softmax activation function will point to the class to which the species belong to. The mathematical function for skip connections between units is

$$g(y) = f(y) + y \quad (3)$$

$h(x)$ is the unit's output, and x is the previous unit's input. Therefor,

$$h(x) = f(x) – x \quad (4)$$

VI. Interpretation

Deep learning is always considered a black box experiment. Whenever a model makes a prediction, there is no clear explanation of why it predicts the way it predicts. When the model makes a prediction, it is hard to determine the underlying mechanism that makes the model predict that way. Interpreting the model answers the above problem.

Fig. 2: Sample of Images from the Dataset

LIME [6] (Local Interpretable Model-Agnostic Explanations), considers local features that are used to make the interpretation. The figure below shows the different regions that are taken for classification. This makes it clear that the model is predicting the species based on dragonfly itself but not based on grass or anything else.

We also recorded that the model got confused between more visually similar species. For example,

- Two Copera species - *Copera Vittata* and *Copera Marginipes.*
- Two Ceriagrion species - *Ceriagrion Chromothorax* and *Ceriagrion Coromandelianum.*
- Two Lestes species - *Lestes Viridulus* and *Lestes Elatus.*
- Two Libellago species - *Libellago Lineata* and *Libellago Indica.*
- Between *Orthetrum Pruinosum* and *Crocothemis Servilia.*
- Between three Pseudagrion species - *Pseudagrion Indicum*, *Pseudagrion Microcephalum* and *Pseudagrion Malabaricum.*
- Between *Aciagrion Occidentale*, *Agriocnemis Pygmaea.*

Fig. 6 shows the visual similarities between the species. We can infer that the damselflies are among the most confused one's.

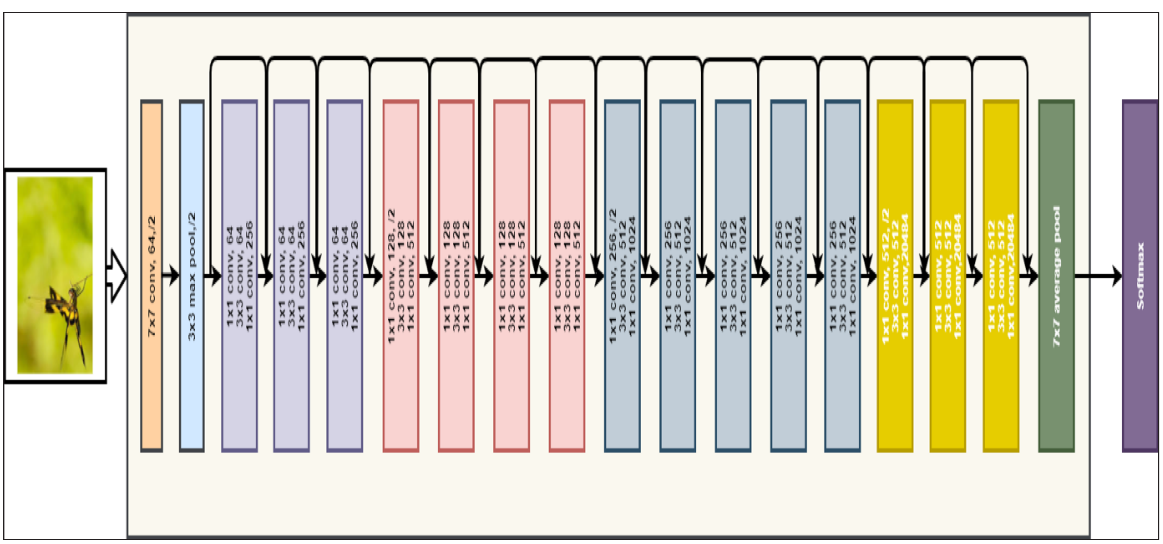

Fig. 3: Dragonfly-Net Architecture

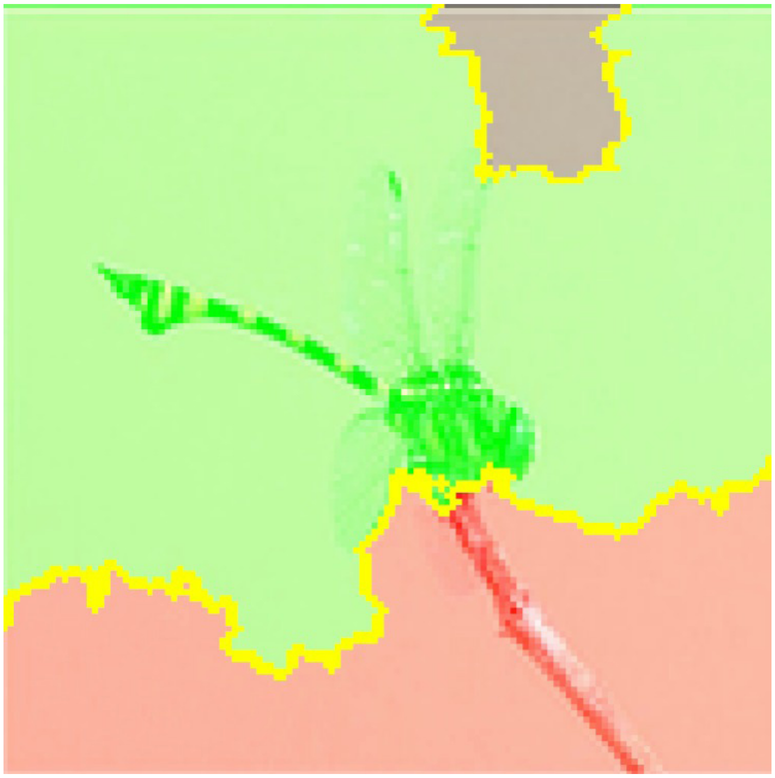

Fig. 4: *Ictinogomphus Rapax* under LIME

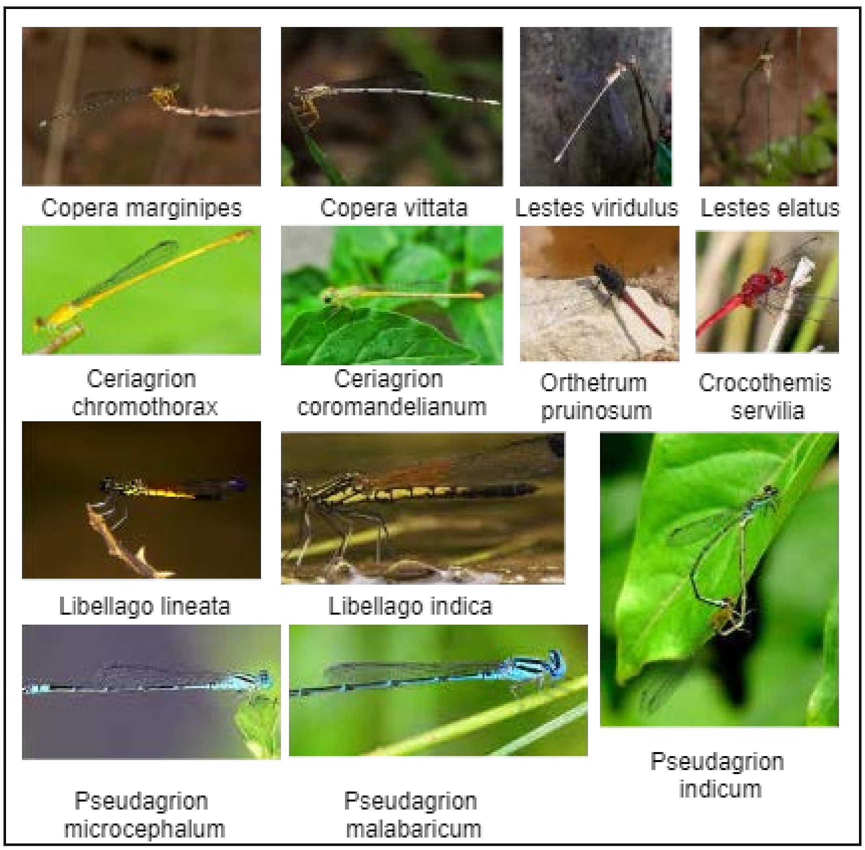

Fig. 5: Most Confused during Prediction

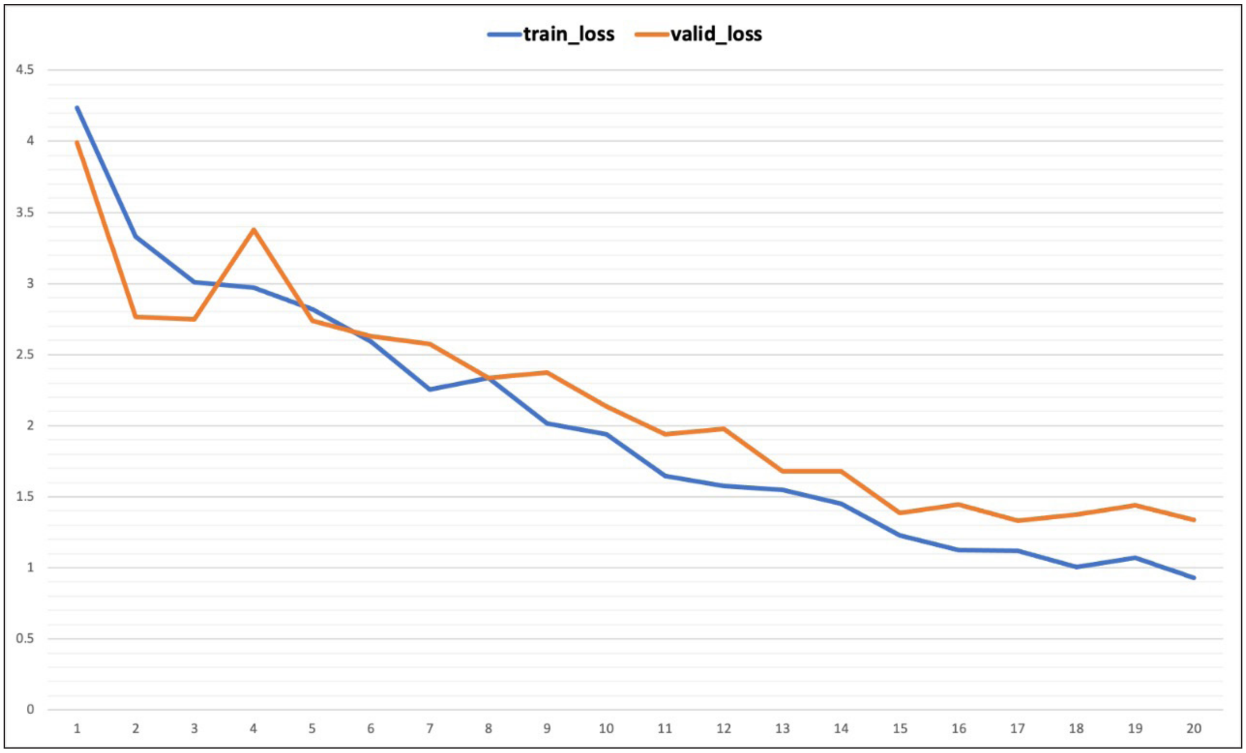

Fig. 6: Training and Validation Loss

VII. Results

To analyze the results of the model, a confusion matrix was constructed, and the accuracy is calculated using the formula,

$$Accuracy = \frac{TP + TN}{FP + FN + TP + TN}$$

The below graph shows the decreasing training and validation losses, which intern resembles increasing accuracy.

In the above figure, the blue line indicates a reduction in training loss, and the orange line shows the variation of validation loss.

The model's training accuracy is the ratio of correct prediction it makes during the course of learning. This is recorded at 76.99%. The validation accuracy, the performance of the model, while predicting the validation data set. This 67.59% and finally, the accuracy calculated during, prediction of hold-out data, recorded at 61.35%.

The reasons for these numbers are assumed as minimum available data, complex and large number of features. Interspecies and intra-species similarities.

VIII. Conclusion

We collected a database that consists of 7000 and odd dragonfly images belonging to 94 different species. The dataset was validated with the help of experts in the field. Later the dataset is taken for cluster analysis. A VGG16 model is used to extract the features followed by dimensionality reduction using the TSNE, estimate parameters for DBSCAN using the elbow method, and cluster the images using DBSCAN. We found out that the cluster purity is 0.7443 F-score is 0.7664.

To identify the model's working with damselflies, we introduced few damselflies, closer cousins of dragonflies. They don't have many visual differences other than much slender body and folding wings. We observed that model confused identifying different damselfly species.

A novel approach to identify dragonfly species given an image, dragonfly-net is constructed. The presented work was inspired by residual neural networks, with skip connections between the layers and, finally, a softmax to give each class the probability values. The training, validation, and testing accuracies are 76.99%, 67.59%, and 61.35%, respectively.

IX. Future Work

The database we gathered contains 94 species out of 300 and odd species available in India. The main reason being, lack of availability of images over the internet.

The complex and shared features among the species and the same species' males and females influenced the false prediction. Future work will seriously consider these issues and propose the approaches that can do the multilabel, multi-class classification of the dragonflies.

The future work is also intended to expand the database to contain all available species in India with a minimum count. Train the whole database over the available architecture and build a new architecture to identify the species with more accuracy.

The expanded dataset will not be limited to Dragonflies but also Damselflies as well.

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