Multi-Genera Classification of Mosquitoes Using CNN on Wingbeat Sound Features

Rose-Mary O.M Gyening,
Nutifafa Y. Agbenor-Efunam, Lakyiere Alice,
Edmund Ilimoan Yamba, Kingsley Badu

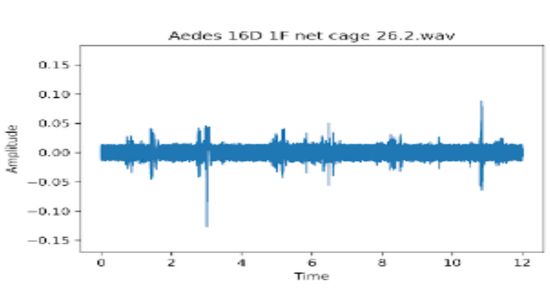
Abstract

Research into classifying mosquitoes using wingbeat frequency offers a non-invasive, cost-effective alternative to traditional morphological and genetic identification methods, enabling early and precise species or genus identification. This study introduces a novel dataset of audio recordings, comprising of a total of 76,032 recordings of three mosquito genera: Aedes, Culex, and Anopheles. A deep learning model was trained using image translations of wingbeat sounds, achieving 92% accuracy. The model holds promise for health applications targeting mosquito-borne disease interventions, particularly in Africa.

Introduction

Mosquitoes transmit diseases that cause over 700,000 deaths annually, highlighting the need for accurate species identification to guide effective control efforts (WHO, 2023). Traditional identification methods are costly, labor-intensive, and reliant on declining taxonomy expertise (Sauer et al., 2024). Machine learning (ML) techniques offer a promising alternative, but most research in this field has been conducted outside Africa. This study aims to address this gap by collecting data on various mosquito genera at different developmental stages and using deep learning models to classify them based on wingbeat sounds.

A sample of Aedes Mosquito



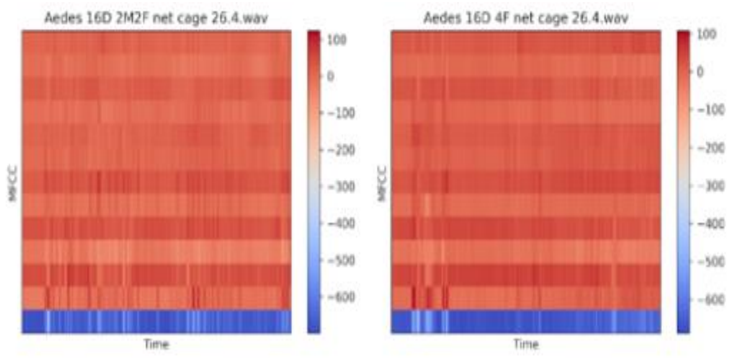
A sample of the Audio Recording of the Mosquito

Methodology

The wingbeat frequency of mosquitoes, which varies by species, age, sex, and environmental conditions, provides critical data for identifying mosquito species and studying their behaviors. Data collection was conducted in a controlled lab environment, maintaining temperatures between 24°C and 27°C. Low-cost microphones placed inside a mosquito net were used to capture the distinct wingbeat sounds of mosquitoes during flight.

Preprocessing Wingbeat Data

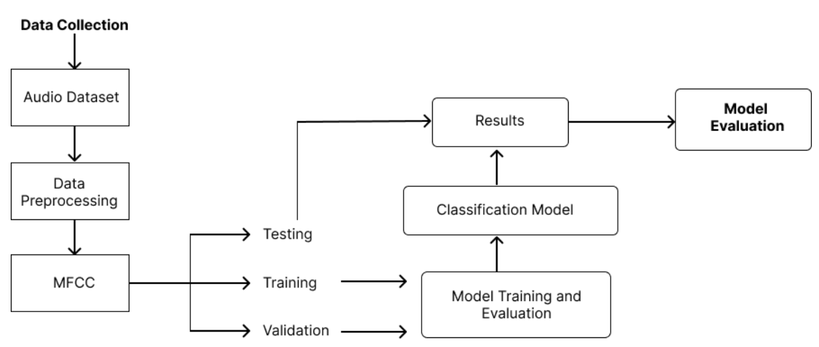
Preprocessing the captured wingbeat audio involved noise removal, normalization, and segmenting the recordings into distinct wingbeat instances. This ensured cleaner and more precise data for analysis. Transforming the audio recordings into images required generating Mel Frequency Cepstral Coefficients (MFCCs). Parameters such as the number of Fast Fourier Transforms (FFT), hub length, and signal characteristics were employed to generate these coefficients, creating visual representations of the audio data.



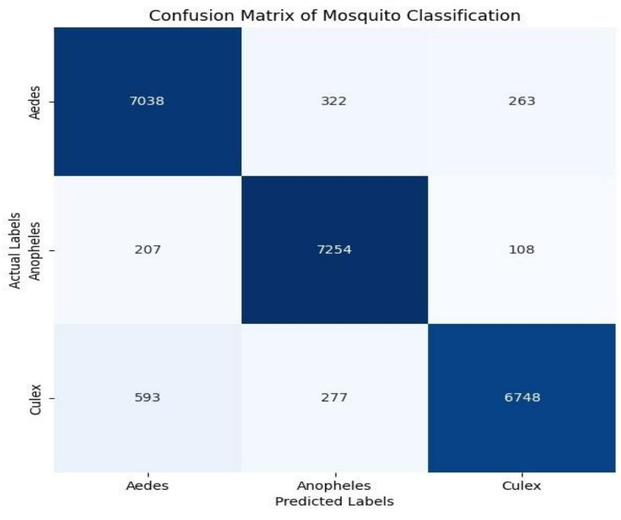
Mel Frequency Cepstral Coefficients (MFCCs)

Model Training and Evaluation

The processed data was used to train a Convolutional Neural Network (CNN) model. The training results are illustrated in the evaluation graph, showing the accuracy and loss of the model over time. Additionally, a confusion matrix was created to evaluate the model's performance in correctly classifying different mosquito genera.

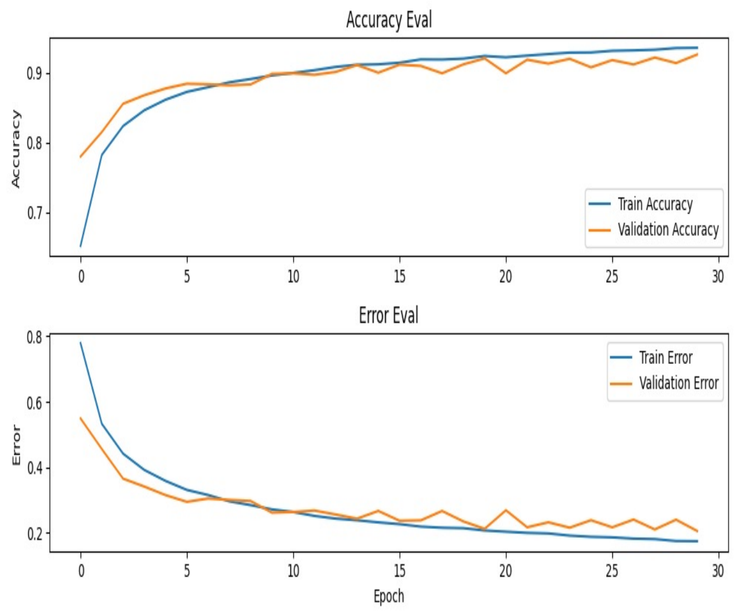


The Training Architecture

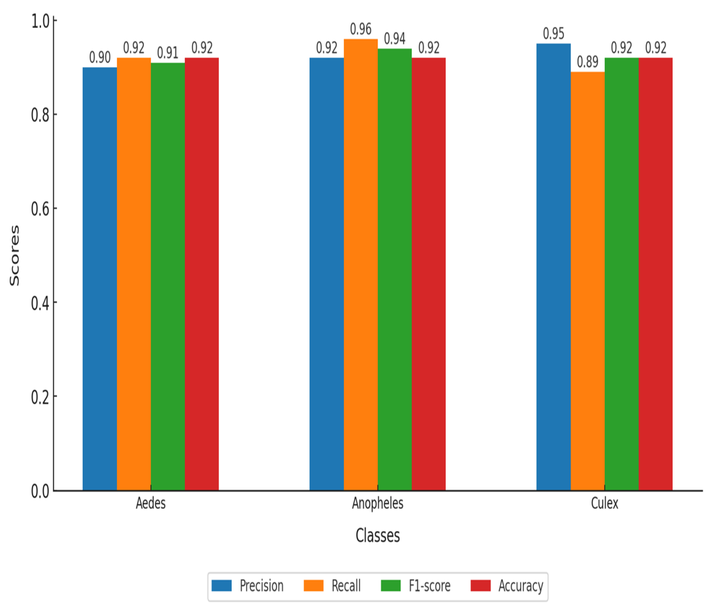


Confusion Matrix of the mosquito classification

Results and Discussion



The evaluation of the accuracy and loss of the CNN model.



The Classification Report of the Proposed Model

Conclusion

We propose deploying this deep learning model on mobile devices as a critical component of a comprehensive public health surveillance system, enabling early detection and warning of potential mosquito-related health threats. Future enhancements will focus on recording mosquitoes in their natural environments, distinguishing between male and female mosquitoes through their wingbeat sounds, and improving the model's effectiveness in preventing vector-borne diseases.

References

1. World Health Organization. (2023). WHO malaria policy advisory group (MPAG) meeting report, 18–20 April 2023. World Health Organization.

1. Sauer, F. G., Werny, M., Nolte, K., Villacañas de Castro, C., Becker, N., Kiel, E., & Lühken, R. (2024). A convolutional neural network to identify mosquito species (Diptera: Culicidae) of the genus Aedes by wing images. *Scientific Reports, 14*(1), 3094. https://doi.org/10.1038/s41598-024-53631-x