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Authors
Rink, Jennifer
Kavuluru, Rohit
Golich, Dannah
et al.

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BEE SPECIES IDENTIFICATION: IMPROVING POPULATION MONITORING TECHNIQUES

Rohit Kavuluru[1], Dannah Golich[1], Jennifer Rink[1], Patrick Moon[1], Navneet Rajagopal[1], Jiashu Huang[1]
Dr. Katja Seltmann[1], Dr. Madeleine Ostwald[2], Dr. Laura Baracaldo Lancheros[3]
[1] University of California, Santa Barbara; [2] Cheadle Center for Biodiversity and Ecological Restoration

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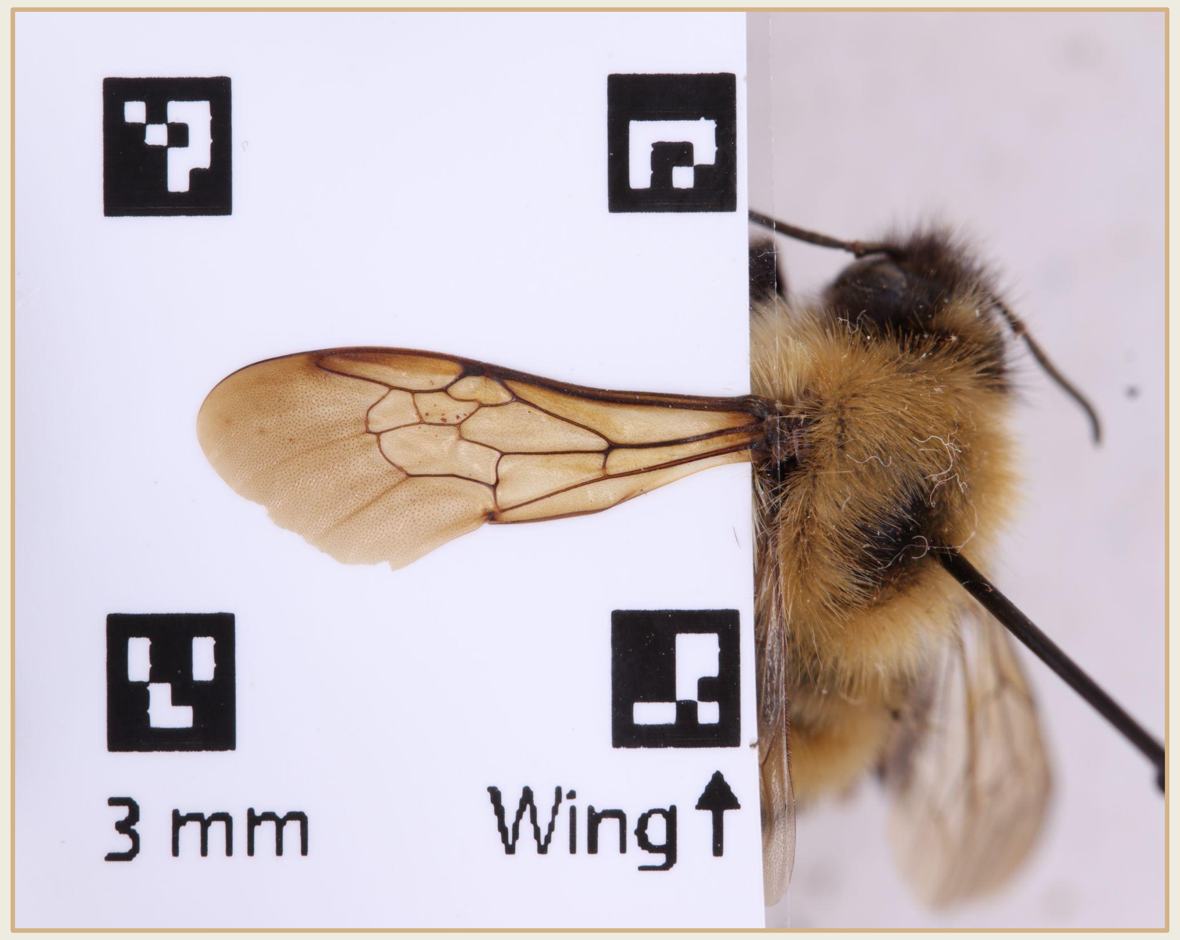

Fig. 1: Example of raw image data, *Bombus vagans*.

Introduction

With a shortage of taxonomic specialists to identify the vast array of bee species, this project aims to **enhance the monitoring of population changes through an automated classification system**, in order to mitigate the critical decline in bee populations which are essential for crop pollination and food security.

A thorough investigation of methods for species classification and the quantification of differences in wing morphology was completed, and includes a convolutional neural network that classifies species with high accuracy, a wing measurement script, explorations of Linear Discriminant Analysis and Spectral Embedding, and a landmark model that identifies geometric differences between species. In order to aid local efforts, a standardization pipeline for field images was also developed that includes perspective correction and cropping.

Dataset

The dataset is a collection of high resolution images of bee wings taken from the samples at UCSB's Natural History Collection at the Cheadle Center. For a majority of the images, the wing is arranged in the middle of four 3 millimeter ARuCO markers. **In total, there are 56 individual species that comprise 15 genera, and have from 2-63 photos each in our dataset.**

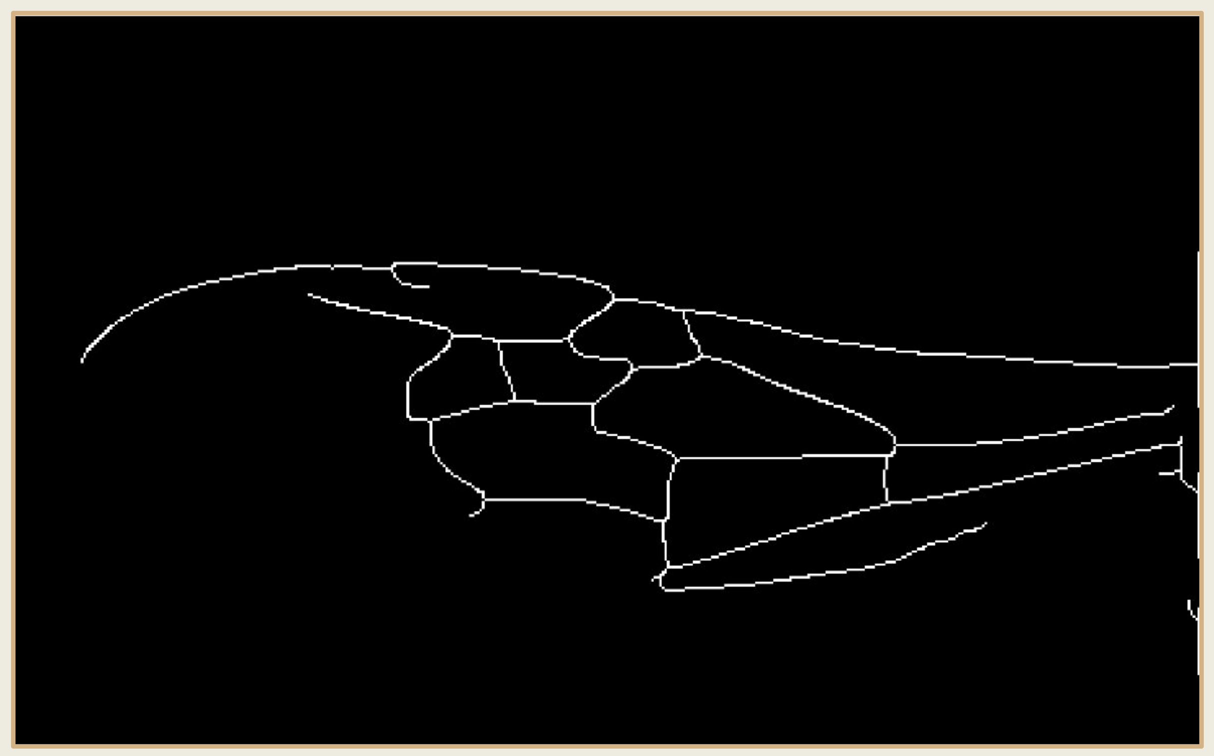

Fig. 2: Skeletonization for landmark model

Summary of Findings

- The VGG 16 model has 13 convolutional layers that learn hierarchical features for accurate classification.
- These layers include ReLU activations and max-pooling, ending with three fully connected layers and a softmax output for classification.
- 95% classification accuracy on testing data across all species.

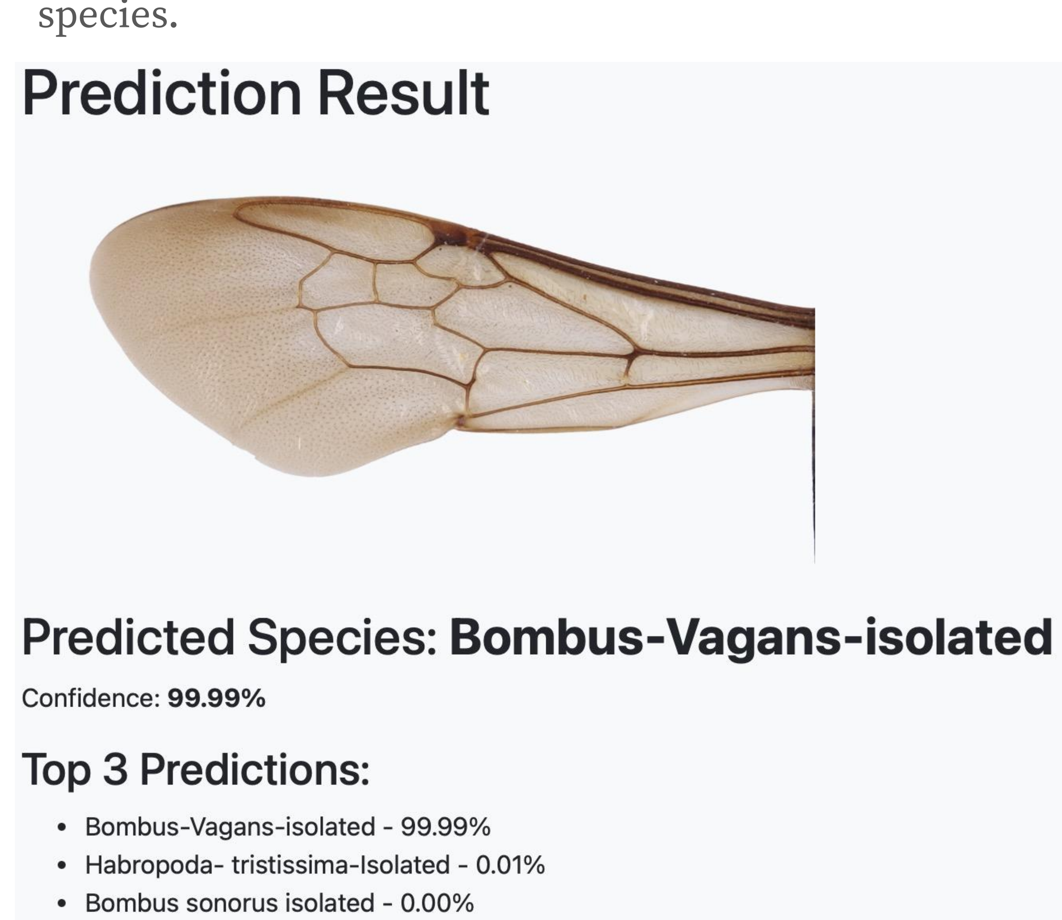

Fig. 3: Example of a VGG-16 Output

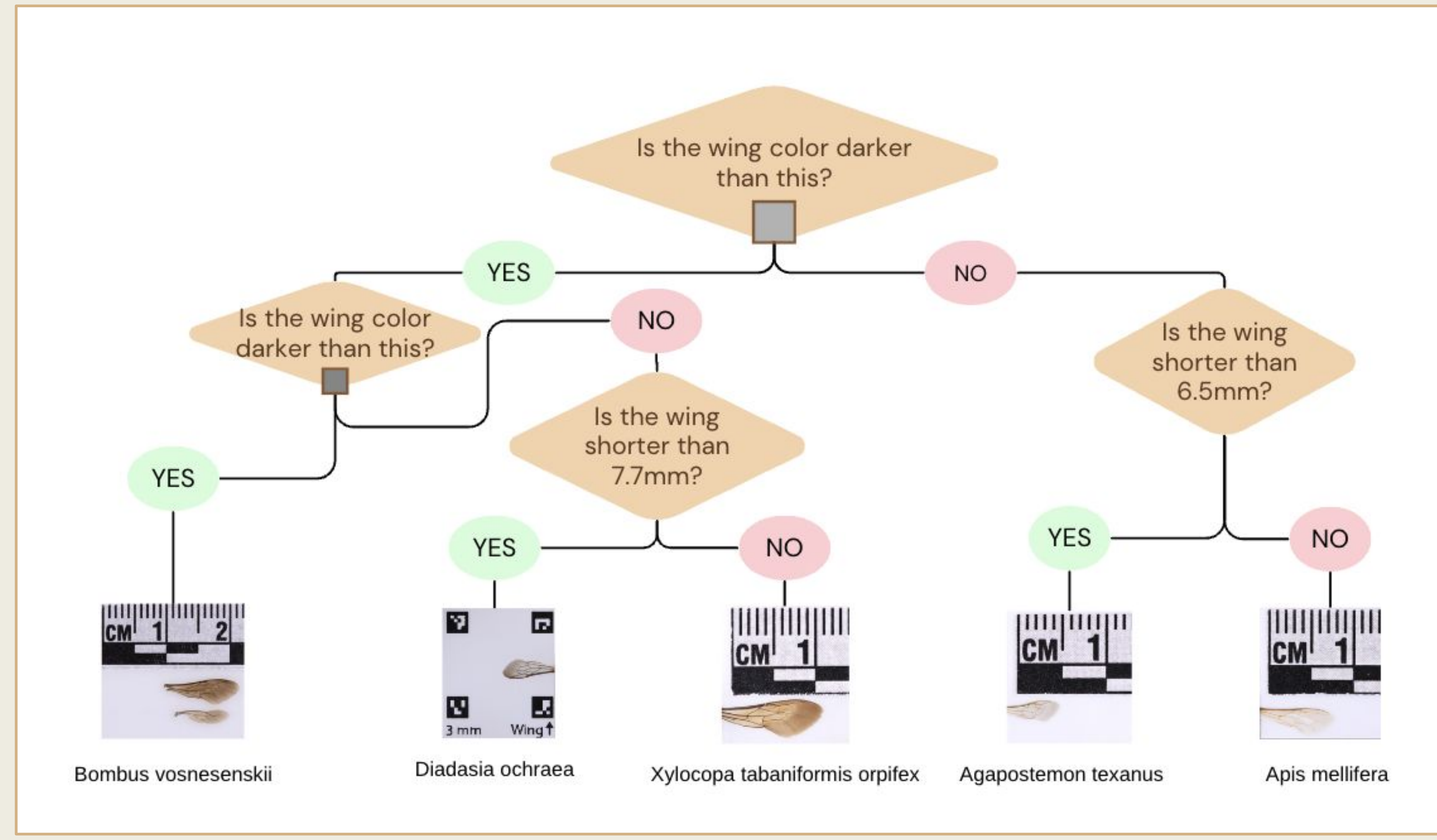

Fig. 4: Visualization of Landmark Model Decision Tree (5 Species)

Methodology

Linear Discriminant Analysis:
- Used VGG16 to extract features from bee wing images, applied LDA to reduce the dimensionality of feature sets, maximizing class separation.
- With LDA-transformed features, created scatterplots, showing clustering of similar species.

Landmark Model:
- Developed pipelines to extract interpretable features from raw wing images (wing length, color, wing angle, etc).
- Integrated the best-performing features with different interpretable models such as decision tree across different species sets.

Outcomes and Impact

The web application will allow researchers to easily upload wing images for species identification and analysis. This user friendly platform provides immediate results, including species identification, wing length measurements, and etc. **By hosting the application online, the web app is accessible to a wide range of users, facilitating broader data collection and collaboration.** Overall, the application will enhance efficiency of bee species identification, supporting conservation efforts. It will also promote widespread collaboration within the scientific community, contributing to more effective biodiversity preservation initiatives.

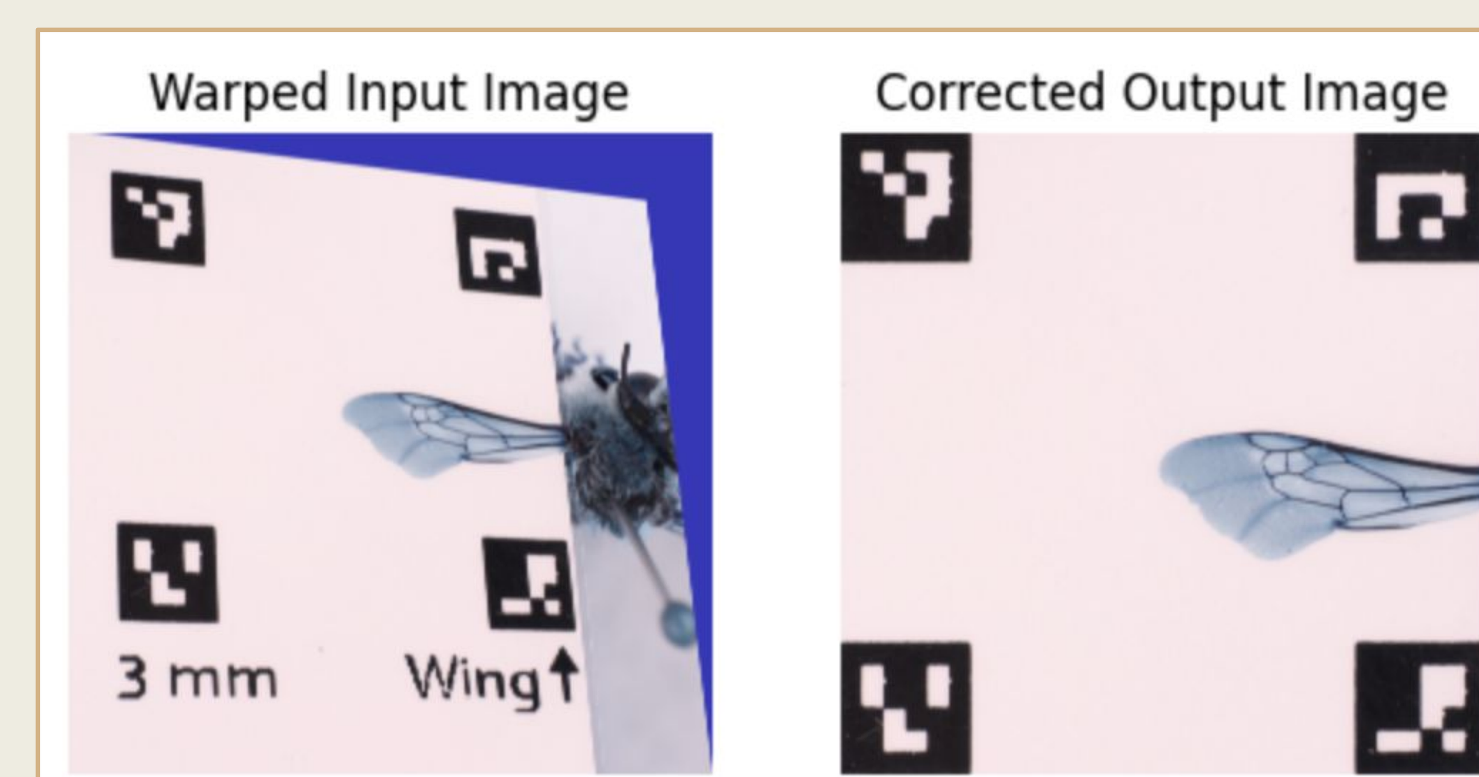

Fig. 5: Field image correction on manually warped image

References and Acknowledgments

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