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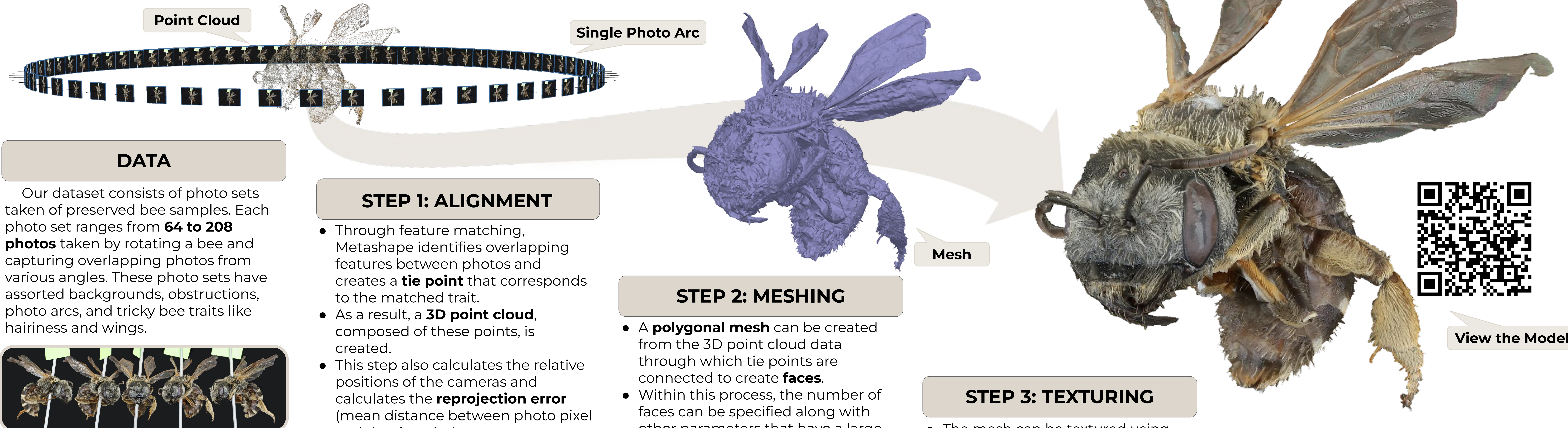
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# THE BIG BEE PROJECT: ADVANCING RESEARCH THROUGH 3D BEE MODELING

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## 3D BEE MODEL RECONSTRUCTION: PHOTOGRAMMETRY PIPELINE



### ABSTRACT

- **Massive declines of bee populations** around the world are a growing concern.
- There is limited information on how physical traits of bees hinder or support their declining populations.
- Photogrammetry proves to be a viable option for creating accurate models of bees which can then be measured and investigated.
- Certain conditions optimize the 3D modeling process and lead to more accurate models.

### INTRODUCTION

Bees are the world's most important pollinators playing a key role in maintaining the health of ecosystems and global food production. However, their populations are declining worldwide; there is limited data on how their physical traits affect their vulnerability. Through the process of **photogrammetry** – a 3D image reconstruction method that uses photos – researchers are able to quantify and investigate these bee traits. **Our project goal is to create 3D bee models using Metashape to help the study of anatomical and volumetric bee traits.**

### DATA

Our dataset consists of photo sets taken of preserved bee samples. Each photo set ranges from **64 to 208 photos** taken by rotating a bee and capturing overlapping photos from various angles. These photo sets have assorted backgrounds, obstructions, photo arcs, and tricky bee traits like hairiness and wings.



### STEP 1: ALIGNMENT

- Through feature matching, Metashape identifies overlapping features between photos and creates a **tie point** that corresponds to the matched trait.
- As a result, a **3D point cloud**, composed of these points, is created.
- This step also calculates the relative positions of the cameras and calculates the **reprojection error** (mean distance between photo pixel and the tie point).

### STEP 2: MESHING

- A **polygonal mesh** can be created from the 3D point cloud data through which tie points are connected to create **faces**.
- Within this process, the number of faces can be specified along with other parameters that have a large effect on the resulting mesh. Insufficient faces can lead to holes or fragmentation.

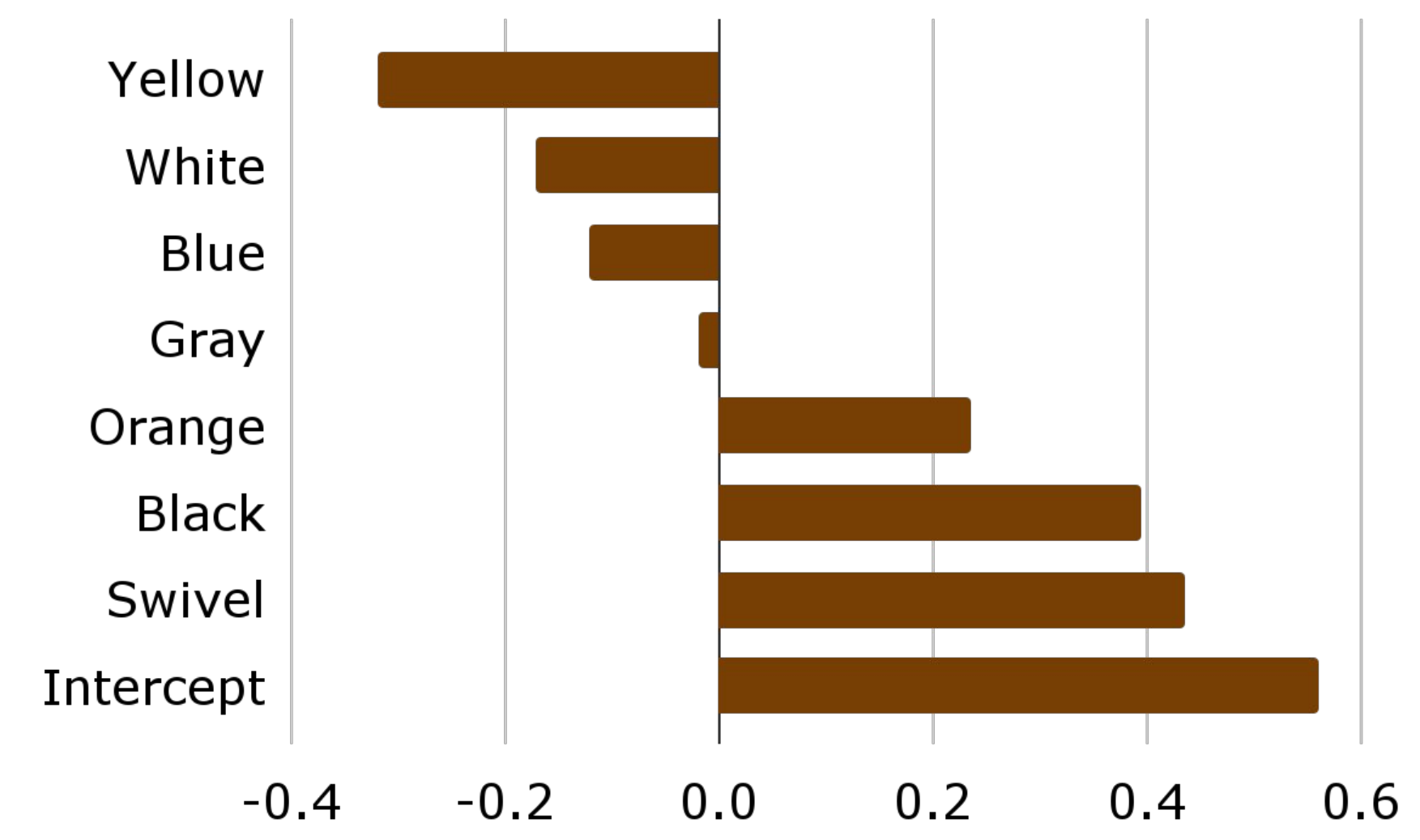
### STEP 3: TEXTURING

- The mesh can be textured using image data from the original photos to create a photorealistic reconstruction of the subject.

## KEY TAKEAWAYS AND DOWNSTREAM APPLICATIONS

### RESULTS

- Sixteen fully textured bee models of nine different species of bees.
- Segmentation of body parts (head, abdomen, thorax) used for volumetric measurements.
- Step-by-step guide documenting methodology for reproducing results and troubleshooting.
- Thorough exploration of various photo-features and their effects on the resulting 3D models and their reprojection error.



**Figure:** Coefficients for Estimating Reprojection Error Based on Background Color and Swivel Arm Obstruction

### SUMMARY OF FINDINGS

- High-definition photos result in capturing more tie points which improves alignment and model quality.
- **Low reprojection error implies more accurate points, but not a better-looking model.**
- Reducing photo quantity to around 50 photos significantly reduces modeling time while maintaining model accuracy.
- Consistent black backgrounds that contrast with the bee significantly shorten the masking process.
- Capturing photos from multiple overlapping arcs reduces rendering errors such as holes, but requires a larger amount of tie points.
- The tweaks tool in Metashape greatly enhances the quality of bee wing renderings.



**Figure:** Unmasked, no tweaks vs. masked, with tweaks

### MODEL APPLICATIONS

- Expand model-making using our documentation on methodology to bee samples across institutions.
- Create a dataset of volumetric measurements that includes body parts, surface area, and lengths of appendages.
- Use the 3D bee models to train a Machine Learning (ML) Model to recognize bees in camera traps for ecological studies.
- Statistical study to explore factors that hinder the survival of bee populations and those that help their survival.

### REFERENCES AND ACKNOWLEDGMENTS

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