CS 5330: Pattern Recognition & Computer Vision
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Segmentation and Auto-labeling of Insect's Legs Using Machine Learning for DeepLabCut

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Introduction

- Accurate labeling of anatomical features is crucial for understanding complex behaviors, especially in insects with intricate leg structures and dynamic movements.
- Manual annotation of insect behaviors is time-consuming and prone to errors, emphasizing the need for automated solutions.
- DeepLabCut, a powerful tool for pose estimation, requires manual annotation, limiting its efficiency for large-scale studies.
- Our research focuses on automating the labeling of insect legs within the DeepLabCut framework.
- We aim to leverage advanced image processing and machine learning techniques to streamline the annotation process.
- By automating the labeling of insect legs, we seek to improve the efficiency and accuracy of behavioral analysis in insect studies, facilitating deeper insights into their locomotion and interactions with the environment.

Related Work

- Markerless visual servo control of a servosphere for behavior observation of a variety of wandering animals
- Image processing techniques for insect shape detection in field crops
- A Comparative Between Corner-Detectors (Harris, Shi-Tomasi & FAST) in Images Noisy Using Non-Local Means Filter
- Fly LimbTracker: An active contour-based approach for leg segment tracking in unmarked, freely behaving Drosophila

Framework

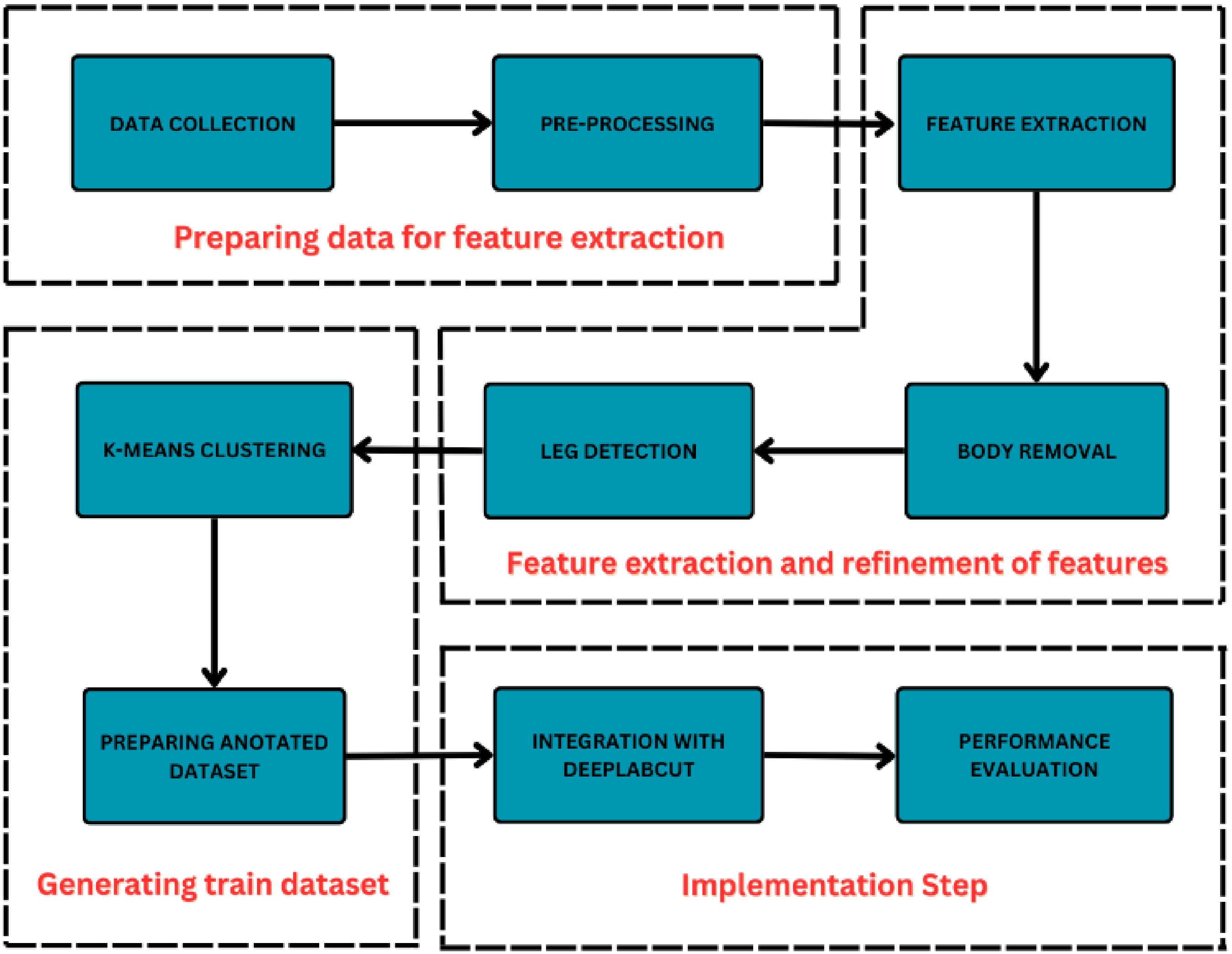

Fig 1. Framework of the Project

Methodology

Data Collection

- Data sourced from ServoSphere, a specialized platform for insect locomotion study.
- ServoSphere comprises a sphere mounted on omni wheels with a high-speed camera for precise tracking.

Pre-Processing

- Grayscale conversion for simplifying computations.
- Gaussian blurring to reduce noise and smooth images.
- Binarization for creating binary representations.
- Morphological operations for noise removal and gap filling.

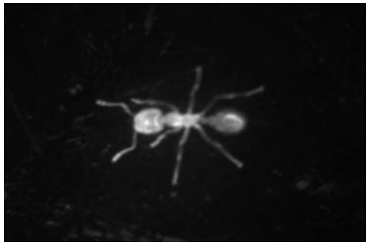

Fig 2. Grayscale Image

Fig 3. Binary Image

Feature extraction:

- Good Features to Track (GFTT) method combines Canny edge and Shi-Tomasi corner detection.
- GFTT identifies salient features along the ant's body and legs.

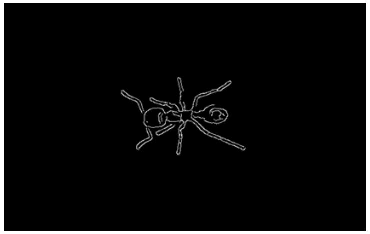

Fig 4. Features from Canny Edge detection Algorithm

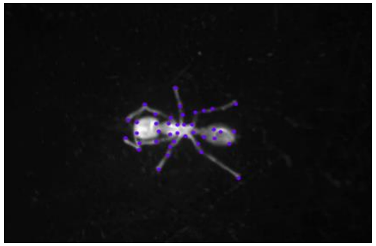

Fig 5. Features from Shi-Tomasi corner detection Algorithm

Methodology

Body Removal:

- Zhang-Suen thinning algorithm extracts the skeleton of the Insect's body.
- Connected components labeling separates and identifies individual leg segments.
- Template matching removes the main body, leaving only the Insect's legs for analysis.

Leg detection:

- Angles between detected feature points and centroid along horizontal axis used to distinguish legs.
- K-means clustering partitions feature points into clusters based on angles.
- Clustered points identify potential leg tips for further analysis.

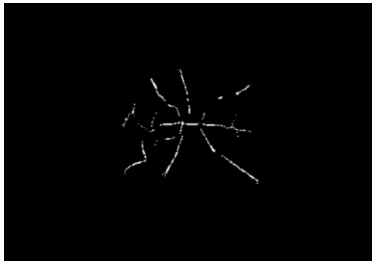

Fig 6. Skeloton Image

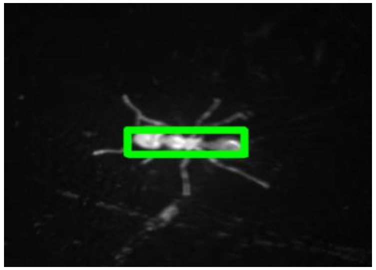

Fig 7. Template Creation

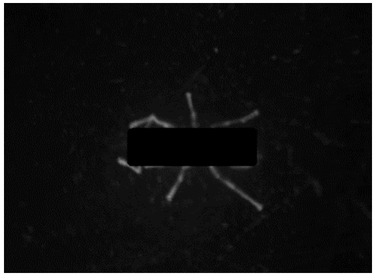

Fig 8. Body Removal

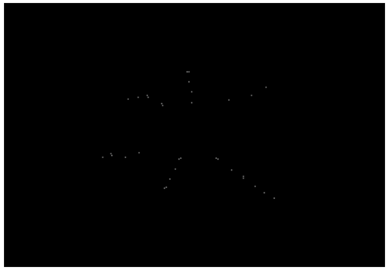

Fig 9. Features corresponding to Insect’s legs

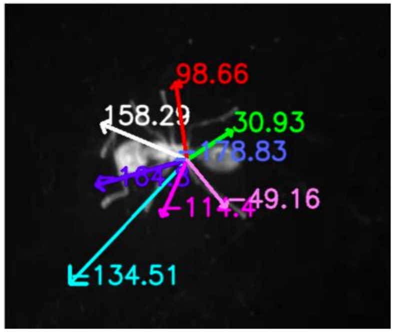

Fig 10. Angles corresponding to different legs w.r.t horizontal axis

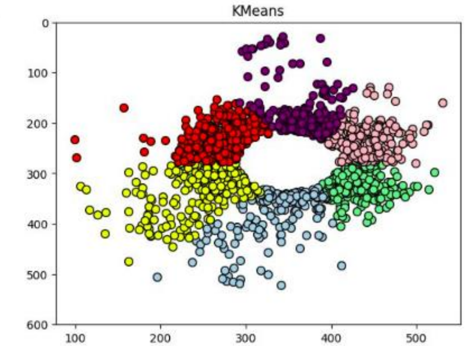

Fig 11. Clustered features using KMeans Algorithm

DeepLabCut Integration

- DeepLabCut is an Efficient method for 2D and 3D markerless pose estimation.
- Utilizes transfer learning with deep neural networks..
- Annotated dataset prepared for training using automated labeling techniques.
- Seamless integration with DeepLabCut for precise movement tracking in video recordings.

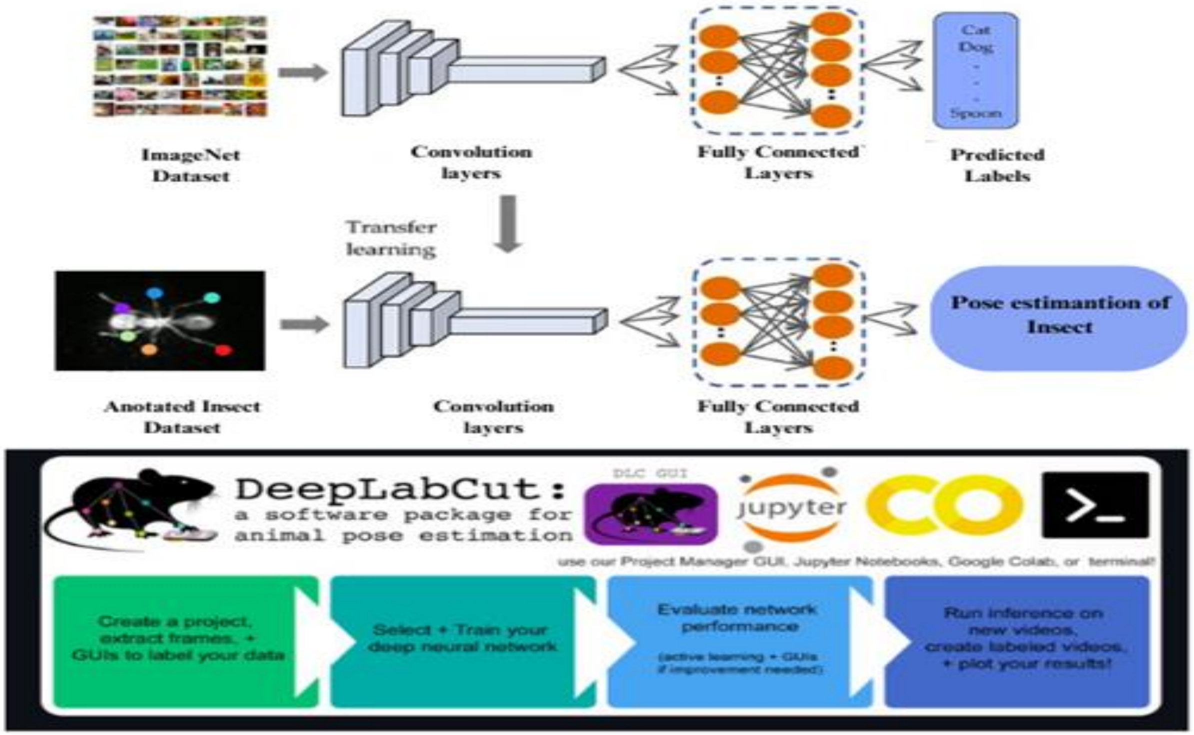

Fig 12 . Integration with DeepLabCut Model

Performance Evaluation

Table 1. CONFUSION MATRIX

Leg Type	True Positive (Auto)	False Positive (Auto)	True Positive (Manual)	False Positive (Manual)
Leg 1	95	2	98	1
Leg 2	90	3	95	2
Leg 3	85	4	90	2
Leg 4	80	3	85	3
Leg 5	75	5	80	4
Leg 6	70	3	75	3

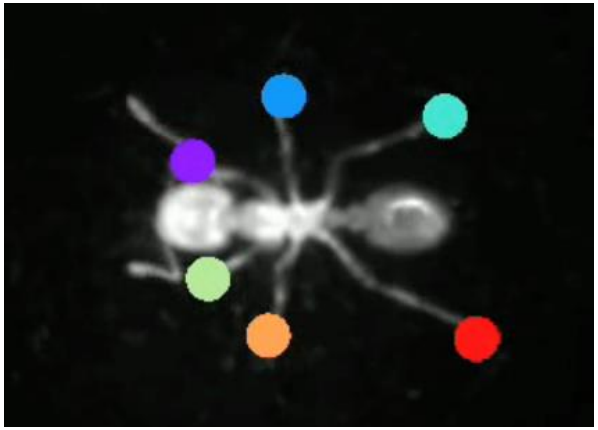

Fig 13. Tracking the movement of Insect's legs

- The matrix revealed a high degree of accuracy with our automated method, although slightly below that of manual labeling

Conclusion

- Shi-Tomasi Corner Detector (Good Feature to Track) outperforms ORB and FAST in this task
- KMeans outperforms Ensemble KMeans in providing clearer clustering of leg features
- Canny Edge Detection and Morphological Operations enhanced image quality for more effective feature detection
- Template matching proves to be more effective at removing main body part of the insect than blob detection

THANK YOU