Automated Drosophila Sorting System

ECE 4960: Team 8

Dylan Britch (EE), Ainara Garcia (CpE), Rivers Henderson (CpE, EE), Camren Khoury (CpE, EE) , William McGlone (EE), Megan Mcnuer (EE), Avi Patel (CpE)

Holcombe Department of Electrical and Computer Engineering, Clemson University, Clemson, SC

Abstract

Comprehensive mechanical design with re-printable, modular components supporting future iterations. YOLO model achieves 95–99% validation accuracy using a ~2000-image dataset. System demonstrates automated classification and sorting at ~2 flies/min. A full control pipeline is integrated into a remotely accessible GUI with debugging. Climbing assay execution and report generation are automated and exported to Box.

Introduction

This project presents the development of an Automated Fruit Fly Sorting System intended to streamline routine laboratory procedures. The system serves as a proof of concept for automated fly sorting, loading, and climbing assay execution through the integration of computer vision, motion control, and custom hardware. The overall goal is to reduce manual effort, improve repeatability, and support more efficient research workflows.

Objectives and Goals

Automate sorting of Drosophila Melanogaster from bulk input (~40 flies) into experiment-ready groups.

- Hold/Sedate Flies
- Design + Print Parts
- Wiring + Motor Control
- Sex Flies at Rate of 4/second with > 80% Accuracy
- Automate Climbing Assay Experiment
- Budget < $600

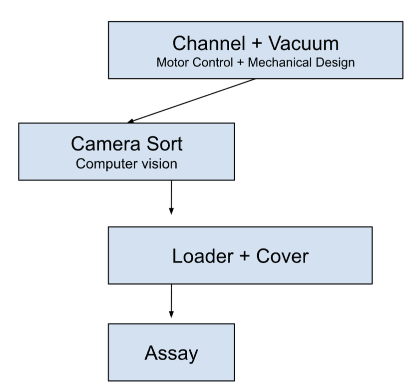


Fig.1: Block Diagram of Four-Phase Process

Methods

3-D Design

ITEM NO.	PART NUMBER	ITEM NO.	PART NUMBER
1	Table 3.0	8	Pi Shelf
2	Camera Box	9	Channel Camera Stand PARTS ASSEMBLY
3	Camera Box Top	10	Assay Tube Holder 3.0 Assembly
4	Channel	11	Assay Camera Stand Total Assembly
5	CO2 Attachment	12	Assay Camera Box 2.0
6	Stepper Holder	13	LED Holder
7	PCB Stopper 3.0	14	Electric Motor Holder Assembly

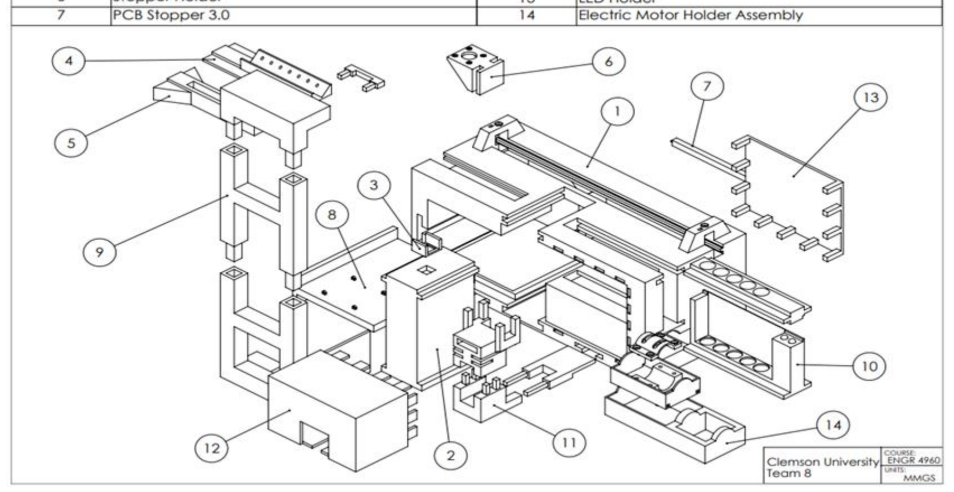


Fig. 2a: Exploded view of the fully implemented table design

Fig. 3: Full Implementation of Design

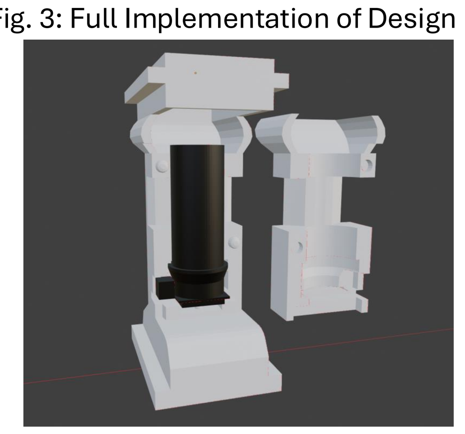


Fig. 4: Microscope Fixture with Light Chamber

Modeling Softwares: Solidworks, Blender

Printed in **ECEntials** lab

Computational Design

- Raspberry Pi 5 8GB
- 1 x Pi HQ Camera with Microscope Lens
- 2x Logitech Brio Webcam

GUI and Networking

- FastAPI + HTTP Remote Control
- Automated Boot Scripts for API
- Remote Control GUI
- OS Compatible (Mac, Linux, Windows)

Software Design

- Python 3.10:
  - GPIO/PWM Control
  - CV/ML Pipelines
  - OpenCV
  - Ultralytics
  - Pillow

Fig.5: Primary Dependency Stack

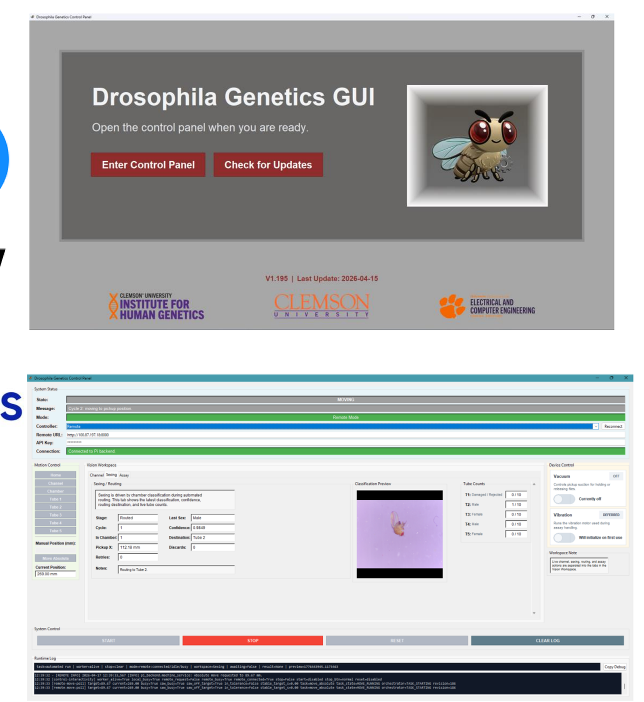


Fig. 6: Remote Control GUI

YOLO + Segmentation Hybrid Model

- Trained and compared 60+ model setups.
- Tried various preprocessing strategies, model sizes, loss functions, and optimizer combinations.
- 28 features from segments, using YOLO output as 2 more. Hybrid result is resistant to overfitting from smaller dataset.

Channel + Assay Detection

- OpenCV used to produce target coordinate for stepper motor gantry.
- Re-scans between movements
- Assay post-processes climb video and generates report on climbing distances and speeds

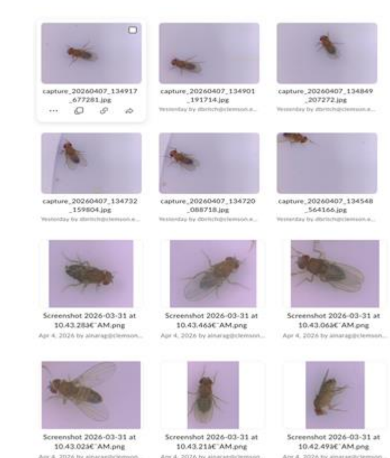


Fig. 7: Database Pictures

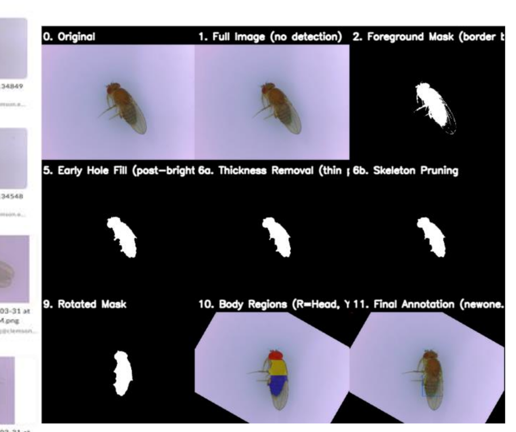


Fig.8: Segmentation Partial Pipeline

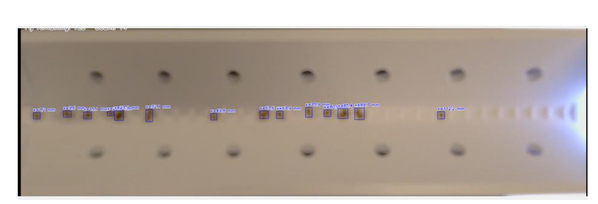


Fig.9: Channel Detection

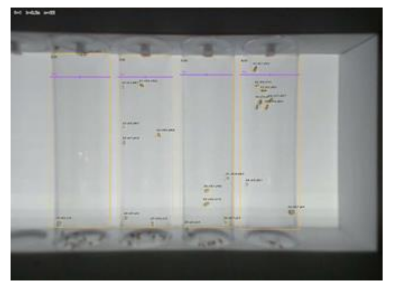


Fig.10: Assay Fly Tracking

PCB Design and Wiring

- Designed on KiCAD, Ordered with JLCPCB, Soldered in ECEntials Lab
- 12V/3A Barrel Jack Input
- Traces: Power: (12V, 3A) Signal: (3.3V, 1A)
- Shielded GPIO Ribbon Cable for I/O
- 2x External MD10C Integrated on Board
- 1x TMC2208 Driver
- 12x External Motor Signal + Switch Ports

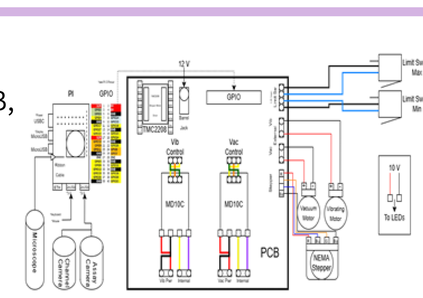


Fig.11:Wiring Diagram

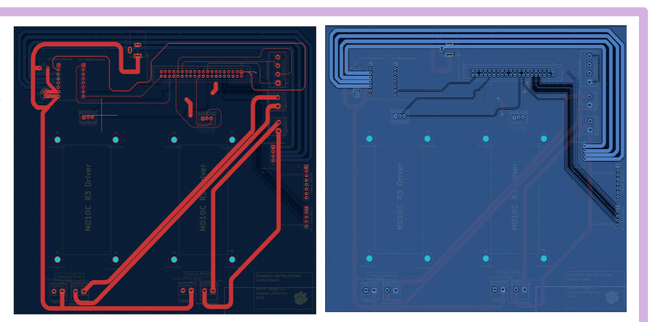


Fig.12: PCB Copper Trace Layout

Gantry Movement and Motor Control

- 12VDC Vacuum Pump
- 12VDC Vibration Motor
- Nema 17 Stepper Motor

Vacuum Nozzle and CO2

- Linear gantry designed using belt, gantry plate
- Vacuum nozzles fitted for flexibility of change
- CO2 Fitting designed for IHG lab ease of implementation
- Channel Designed with evenly distributed CO2 pathways

Fig. 13: Motor Control Stack

Fig. 14: Linear Gantry System

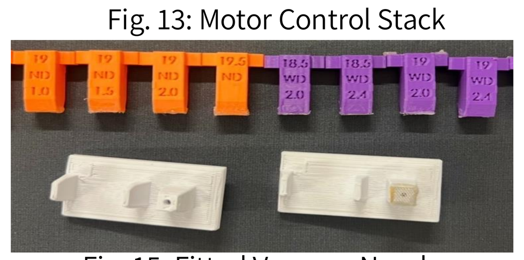


Fig. 15: Fitted Vacuum Nozzles

Fig.16: CO2 Valve Channel Connection

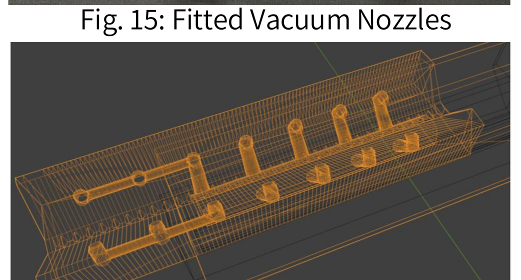


Fig.17: CO2 Diffusion Channel Wireframe View

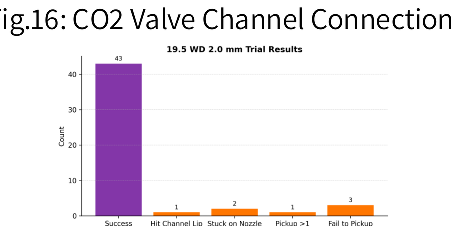


Fig.18: Final Nozzle Success Rate (86%)

Results

- Comprehensive Mechanical Design
  - Components are re-printable and compatible with future iterations in software and other system accessories
- YOLO model has been trained to 95-99% accuracy in 50 sample validation stage, Hybrid trained to 92-94% in 200 sample validation with worse images.
  - Database built to 2000 processed photos
- 2 flies classified and sorted per minute
- Full automated control pipeline integrated in GUI with debug menu complete and remotely accessible
- Assay complete with report generation through GUI and uploaded to BOX
- Instruction booklet complete and integrated clearly

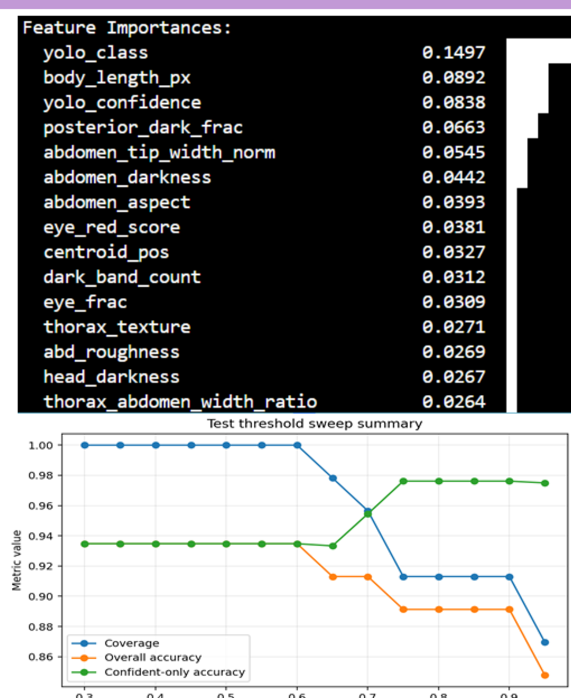


Fig.18: Yolo Model Accuracy + Hybrid Force Plot

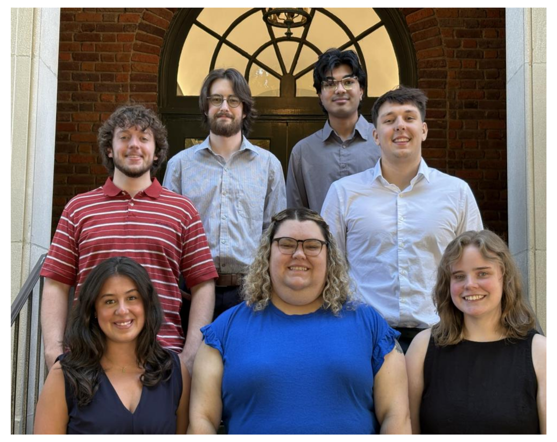
Conclusions

System demonstrates a functional end-to-end automated sorting pipeline integrating computer vision, embedded control, and mechanical subsystems. The YOLO model achieved 95–99% validation accuracy, while real-time system classification performance approached 94% with Hybrid Model under operational conditions. Current throughput is 2+ flies/min with consistent automated handling and assay execution. Results support the feasibility of replacing manual workflows with an integrated and repeatable automated system.

Future Implementations

- Update YOLO model as dataset grows (target: maintain <1% sorting error at ≥4 flies/min); apply color correction to all images including live samples.
- Deploy AI Hat on Raspberry Pi to increase CV framerate (target: sustain real-time detection supporting ≥4 flies/min throughput)
- Refine accessory footprints and interaction design for improved repeatability and to support ≥20 tube fully autonomous operation cycles
- Redesign and correct PCB; integrate motor drivers and LED power supply to support stable 12V system operation and continuous multi-cycle use
- Improve climbing assay: higher resolution camera (≥8MP), handle edge cases, and use flat vials to constrain motion for more consistent tracking
- Increase gantry dimensions (target: expanded travel range) for broader control, improved reachability, and system flexibility

Contact



Dr. Hassan Raza: hraza@clemson.edu

Team (From Top to Bottom, Left to Right)
Dylan Britch: dbritch@clemson.edu
Avi Patel: avi2@clemson.edu

William McGlone: wmcglon@clemson.edu
Camren Khoury: camrenk@clemson.edu

Ainara Garcia: ainrag@clemson.edu
Megan Mcnuer: mmcnuer@clemson.edu
Rivers Henderson: rhende3@clemson.edu

References

1.A. Okemgbo, Z. Lane, A. Cabrera, E. Chaffee, and N. Mahu, *Identifly: Bioengineering 2021 Senior Design - Team 7*, final design report, 2021.
2.Penn BE Labs, “Senior Design 2021 - IdentiFly - Sorting flies for research using AI,” YouTube video, 9:19. [Online]. Available: YouTube. [Accessed: Apr. 13, 2026].
3.Poole, John & Chaturvedi, Anurag, (2026, January 7), “ECE 4960 Projects”, Clemson University Institute of Human Genetics.
4.T. Alisch, J. D. Crall, A. B. Kao, D. Zucker, and B. L. de Bivort, “MAPLE (modular automated platform for large-scale experiments), a robot for integrated organism-handling and phenotyping,” *eLife*, vol. 7, Art. no. e37166, Aug. 2018, doi: 10.7554/eLife.37166.
5.V. Medici, S. C. Vonesch, S. N. Fry, and E. Hafen, “The FlyCatwalk: a high-throughput feature-based sorting system for artificial selection in *Drosophila*,” *G3 (Bethesda)*, vol. 5, no. 3, pp. 317–327, Jan. 2015, doi: 10.1534/g3.114.013664.

Acknowledgements

Thank you to the Clemson ECE Department, ECEntials Lab, and Dr. Hassan Raza for the supplies, tools, and development help. We, also, thank Dr. John Poole, Dr. Anurag Chaturvedi, and the Institute for Human Genetics for supporting this project.

Holcombe Department of ELECTRICAL AND COMPUTER ENGINEERING Clemson University

CLEMSON UNIVERSITY INSTITUTE FOR HUMAN GENETICS