Automatic Calibration of Mosquito Dissection System for the Production of Malaria Vaccine

Team members: Miles Liu

Mentors: Balazs Vagvolgyi, Anna Goodridge

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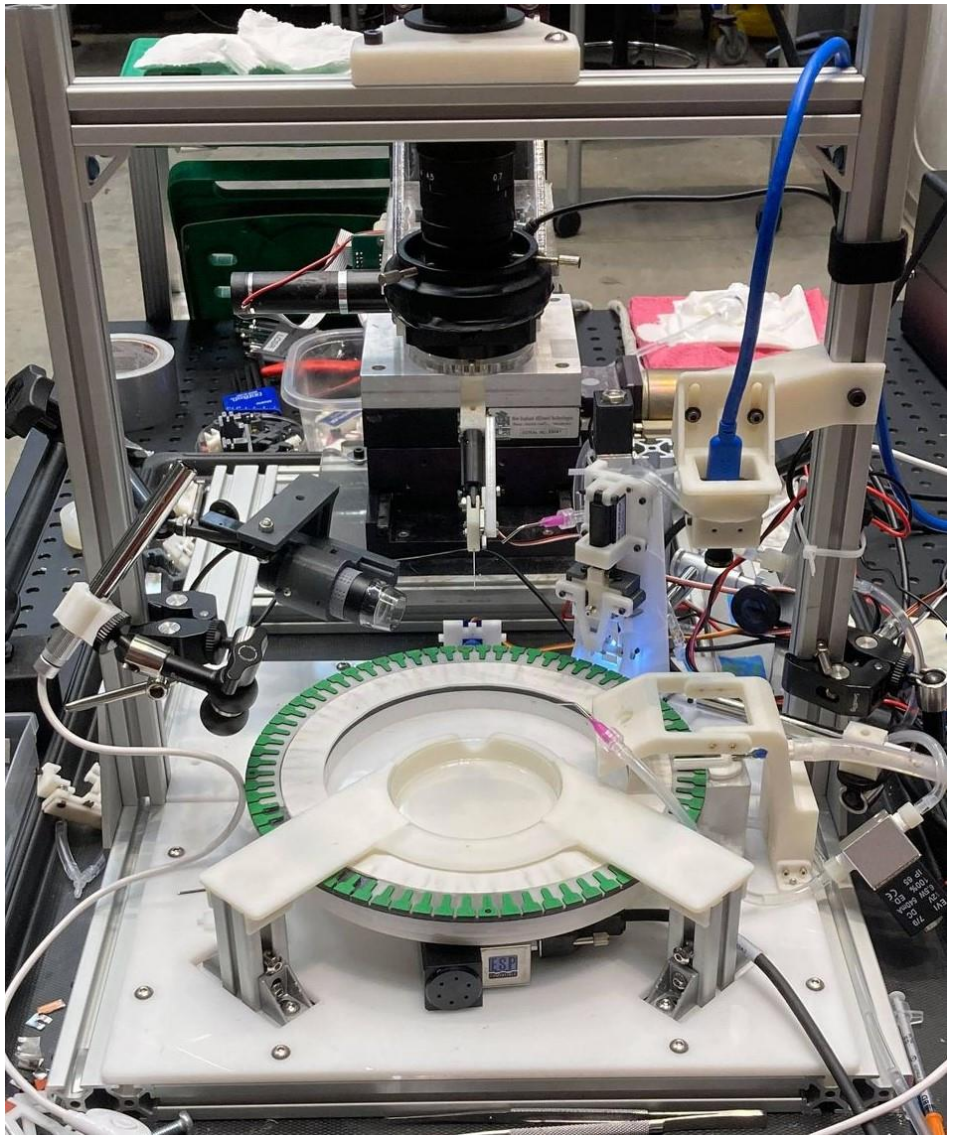
Computer Integrated Surgery II

Project Background

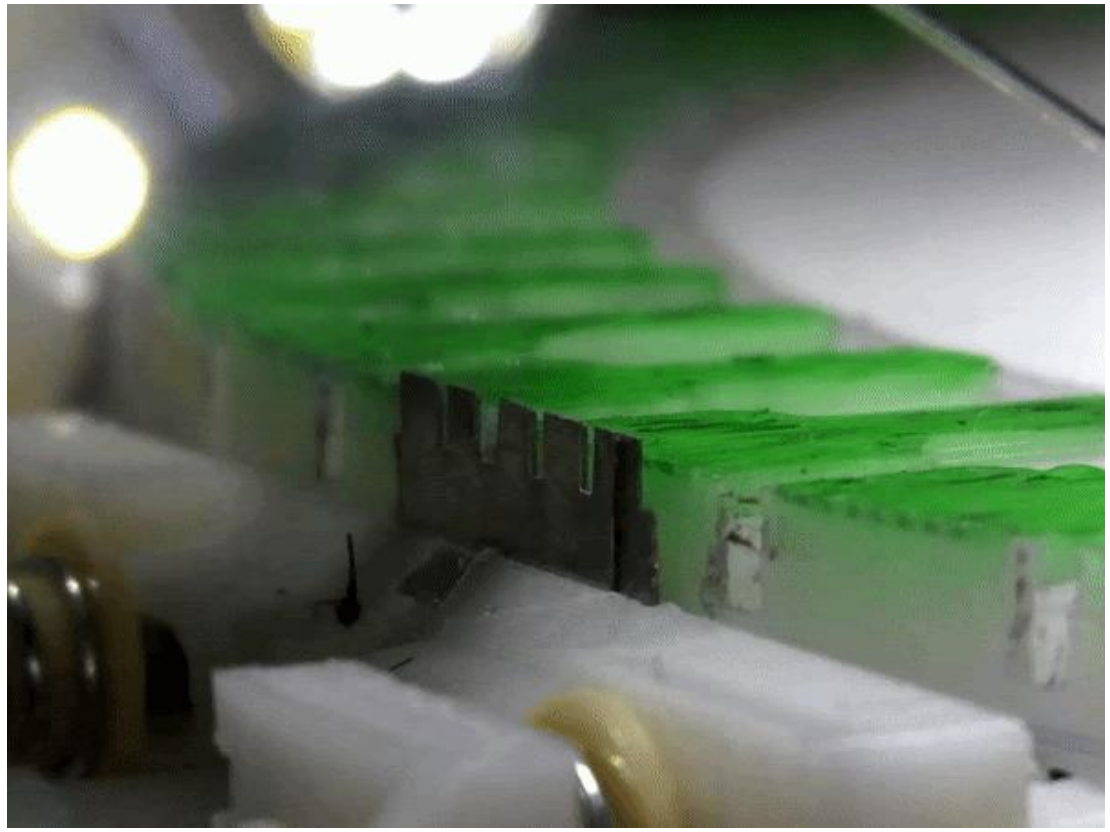
- Sanaria Inc. and CIIS teams have been developing a robot platform to automate salivary gland extraction for vaccine production

- Automated system can significantly increase gland production rates



Project Scope – Streamlining robot calibration

- Robot control needs to be extremely high precision
- Calibration is needed when:
  - Hardware changes
  - Encoder reset
  - Manipulation failure
- Two major calibration components:
  - **Handeye**
  - **Defining robot tool path & homing**

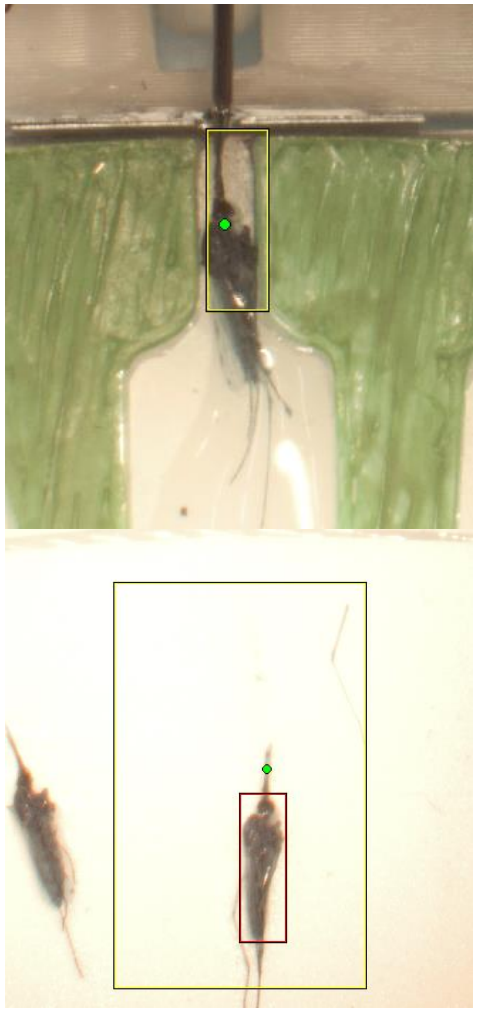


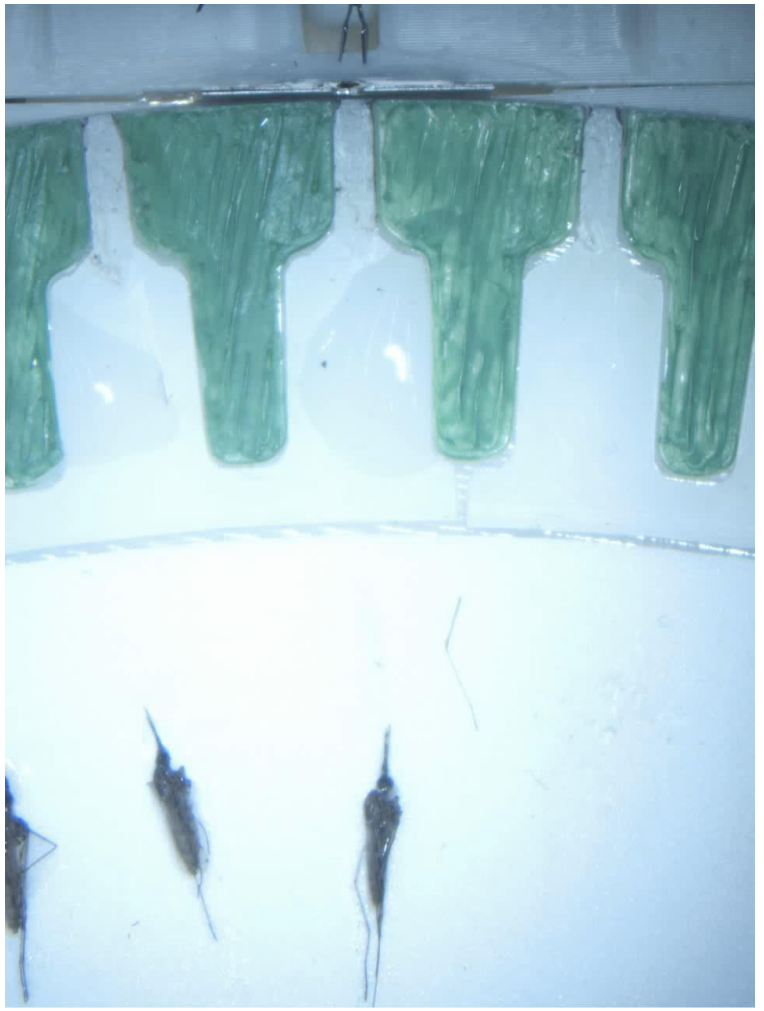
A successful decapitation operation

Handeye Calibration

- Transforms image coordinates to robot encoder coordinates
- Used in all CV processes that involve mosquito manipulation

- Have existing process
  - Outdated
  - Potentially error prone
  - Requires manual intervention and validation

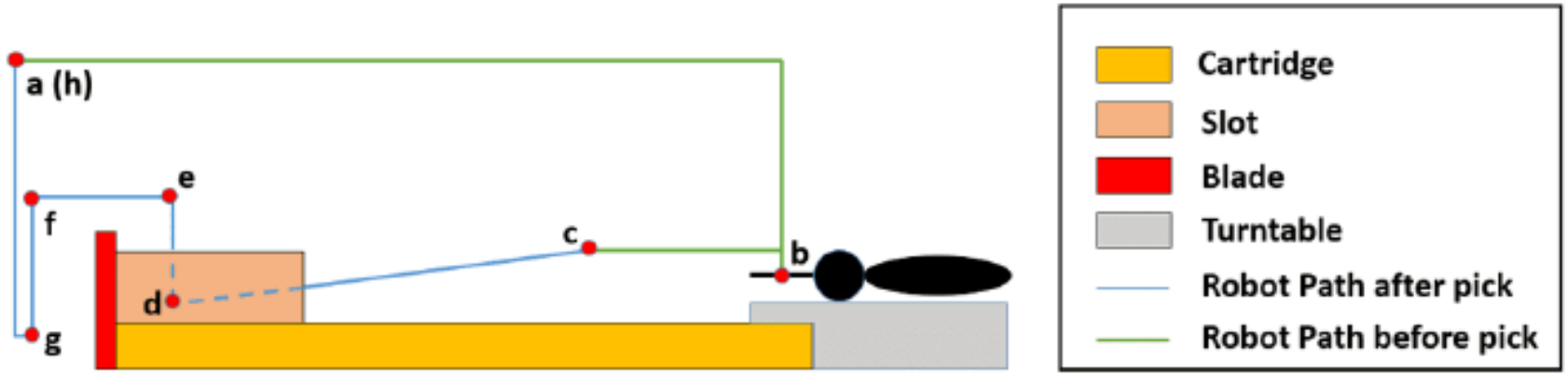




An unsuccessful decapitation operation due to faulty handeye calibration

Calibrating robot tool path & homing

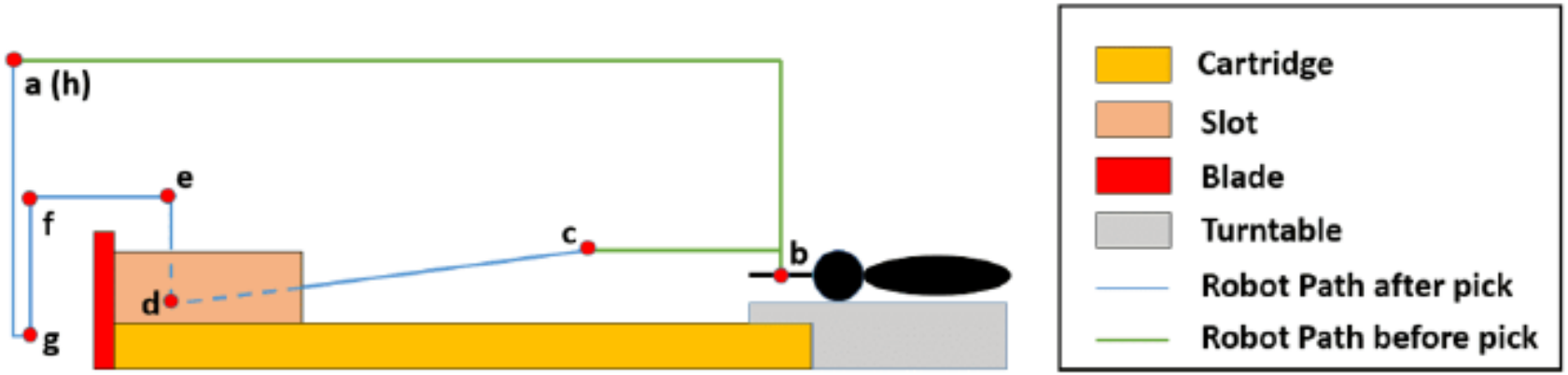
- Robot homing necessary for when encoder positions change unexpectedly
- Robot path for specific operations are not relative to mosquito anatomy but rather to the hardware defined workspace
- Currently, many waypoints are hardcoded absolute positions
  - Labor and time intensive to calibrate
  - Requires frequent recalibration during development



An example robot gripper path (not currently in use)

Project Goals

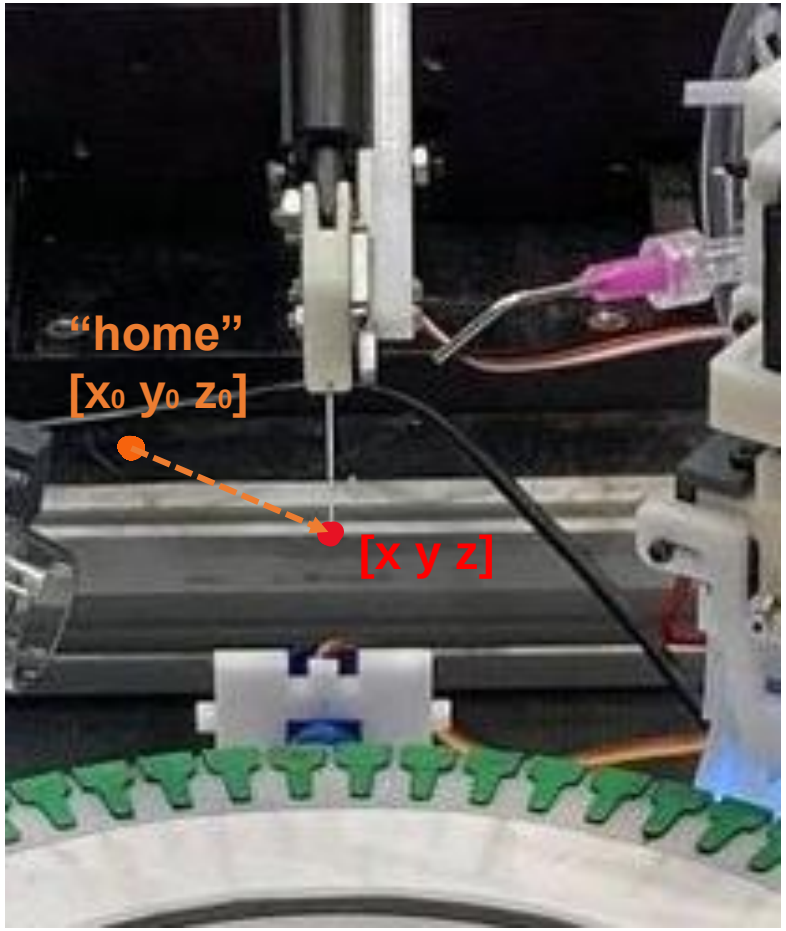
- Streamline and simplify calibration routines, including but not limited to:
  - Streamlined handeye calibration
  - Robot homing
  - Calibration validation
- Rethink how the robot tool paths are defined, and implement a solution that can be maintained easier



An example robot gripper path (not currently in use)

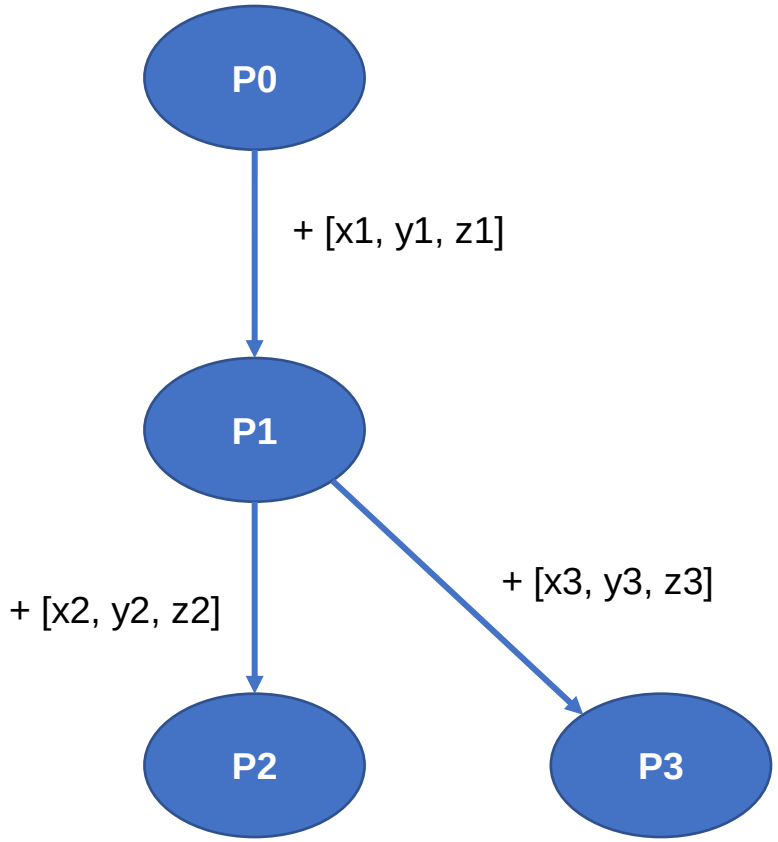
Technical Approach – Robot homing

- Vision based approach
  - Use visual-servoing methods to probe for positions of hardware components
  - Utilize existing cameras
- Hardware based approach
  - Use tooltip to approach and touch a metal fixture, complete an electric circuit, and intercept an electric signal



Technical Approach – Robot tool path definition

- Build a "***calibration tree***" data structure for more intuitive robot tool path definitions
- Rely on homing to define one **0** position, and build all other robot waypoints relative to **0** and each other.
  - Analogous to computational graphs
- All robot operation would then query the tree for path waypoints
- Store object in a human-readable format (e.g. JSON)



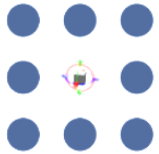
Technical Approach – Handeye calibration

- Existing calibration procedure handles the bulk of calibration, but needs to be neatly packaged
- Plan: wrap calibration procedure as ROS executable
  - Integrates better with new ROS robot software

Packaging Everything

- Utilize ROS GUI tools (rqt) to develop an operator centered calibration workflow

ros-visualization/**rqt**



Project Deliverables

- **Minimum**
  - Streamlined calibration components integrated with ROS
  - Prototype implementation of new "*calibration tree*"
  - Significant progress with development of robot homing calibration procedures
  - Documentation
- **Expected** (continued from minimum)
  - A single calibration workflow & GUI that covers all calibration tasks
    - Robust, ROS integrated
    - Some intervention from the robot operator allowed for robot-homing.
  - Deployment version of the *"calibration tree"*
- **Maximum** (continued from expected)
  - A calibration workflow that does not require any operator input
  - A vision-based calibration validation system
  - Incorporate Sanaria feedback

Project Dependencies

- Availability of station and robot system core components
  - Robot arm, cameras, etc.
  - Potential team conflicts
- Frequency of hardware changes
  - Would affect our ability to consistently test and validate developed procedures
- Availability of support on the vision-based components

Solution

Significant portions of the project deliverables can be drafted and developed remotely or even in isolated dev environments

  - Such as the GUI and calibration data structures

Estimated Project Timeline

- **By End of February**
  - Finalize technical approach, deliverables, and project plan
  - Start cleanup + updating of existing calibration procedures
  - Start implementation of prototype calibration tree and calibration GUI
- **By End of March**
  - Complete update of calibration procedures, verify with in-person testing, wrap into modules
  - Complete prototype implementation of calibration tree and GUI
- **By Mid-April**
  - Conduct first round of testing with developed systems. Identify any system design issues
  - Debug period
- **Late April**
  - Package and finalize deliverables, develop in depth documentation
  - Prepare final poster presentation
- **May**
  - Course end evaluations and poster presentations.

Project Milestones

Item	Expected Completion Date	Status
Research and determine technical approaches	02/28/2022	In Progress
Update and cleanup existing calibration procedures	03/07/2022	In Progress
Prototype implementation of Calibration GUI	03/31/2022	Not Started
Prototype implementation of Robot homing	03/31/2022	Not Started
Prototype implementation of calibration tree	03/31/2022	In Progress
System verification testing on hardware	04/15/2022	Not Started
Modularize components, integrate into calibration workflow	04/20/2022	Not Started
System development and deployment documentation	04/30/2022	Not Started
Solicit user input on system design	04/15/2022	Not Started
Final poster presentation	05/04/2022	Not Started

Management Plan

- Weekly meetings on Zoom on Fridays 2-3PM
- Weekly lab meetings on Zoom on Mondays 10-11AM
- Additional in-lab meetings as necessary

- Code will be maintained on a Git repository
- Documentation, slides, data, will be stored on OneDrive & course website

Reading List

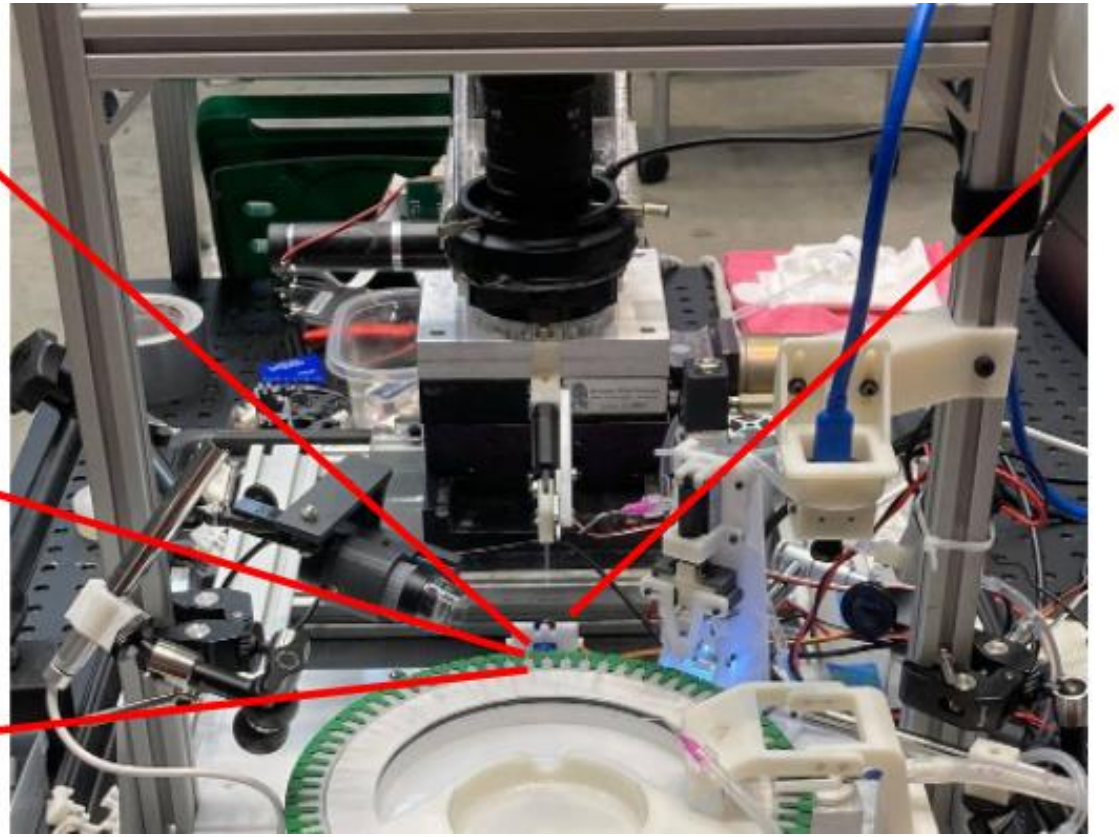
- H. Wu, J. Mu, T. Da, M. Xu, R. H. Taylor, I. Iordachita, and G. S. Chirikjian, "Multi-mosquito object detection and 2D pose estimation for automation of PfSPZ malaria vaccine production", in IEEE 15th International Conference on Automation Science and Engineering (CASE), Vancouver, BC, August 22-26, 2019. pp. 411-417.
- W. Li et al., "Automated Mosquito Salivary Gland Extractor for PfSPZ-based Malaria Vaccine Production," 2021 IEEE International Conference on Robotics and Automation (ICRA), 2021, pp. 866-872, doi: 10.1109/ICRA48506.2021.9560959.

Appendix

4 - CV finds mosquito neck

3 - Robot arm grips and moves mosquito into station

2 - CV finds mosquito body and proboscis



5 - Robot arm brings mosquito to blades, decapitates mosquito

Project focus area: Decapitation station

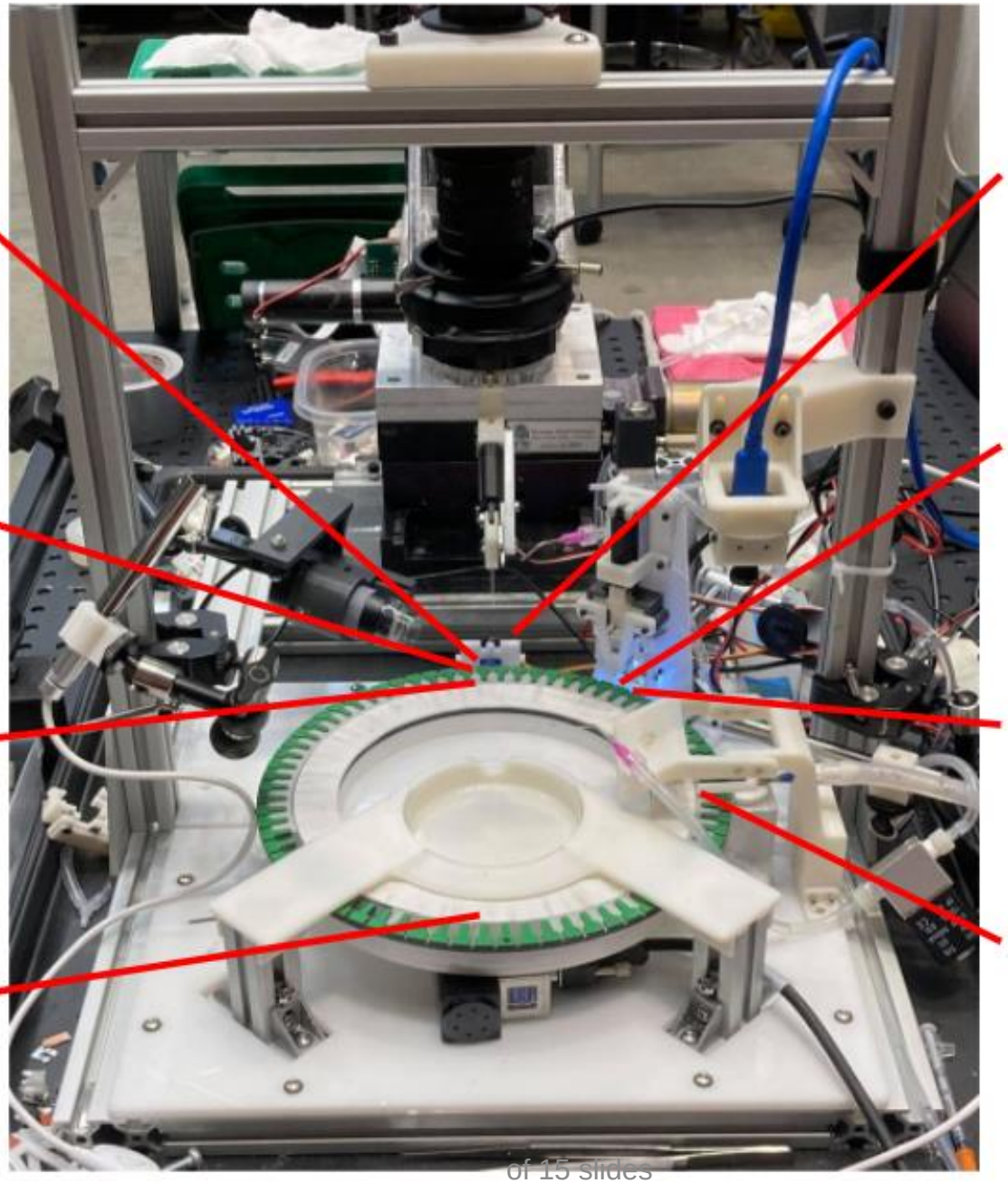
- CV used to identify mosquito anatomy
- 3 DoF prismatic robot to manipulate mosquitos

4 - CV finds mosquito neck

3 - Robot arm grips and moves mosquito into station

2 - CV finds mosquito body and proboscis

1 - Operator places mosquito here



5 - Robot arm brings mosquito to blades, decapitates mosquito

6 - Squeezer presses on torso and exposes salivary gland

7 - Pressurized tube collects exposed gland

8 - Mosquito torso disposed and robot cleaned