

EN 601.656 Computer Integrated Surgery II

**Project Proposal: Automatic Calibration of Mosquito  
Dissection System for the Production of Malaria Vaccines**

03/01/2022

Miles Liu

Mentors: Balazs Vagvolgyi, Anna Goodridge

## Project Background, Importance, and Goals

Sanaria Inc. and the team at Computer Integrated Interventional Systems Laboratory (CIIS) have been working together to develop a robot platform that can fully automate a critical step in malaria vaccine production - salivary gland extraction. Once deployed, this robot platform can significantly increase gland production rates, and thus eliminate this vaccine production bottleneck.

The robot would perform precision microdissection to extract the salivary gland, a process currently done by hand by trained personnel. The current design of the robot uses computer vision to identify key mosquito anatomy, which in turn provides waypoint information to a 3 degree-of-freedom prismatic joint robot arm for mosquito manipulation. The robot system is built in the Robot Operating System (ROS) framework.

As the robot requires high precision mosquito manipulation movements, it will also require precise calibration for many of its components. As the robot is continuously developed, every time hardware parameters are modified, the operator would need to perform a full recalibration of the robot. While there are existing procedures for each of these calibration components, they are fully manual processes, which can be time and labor intensive.

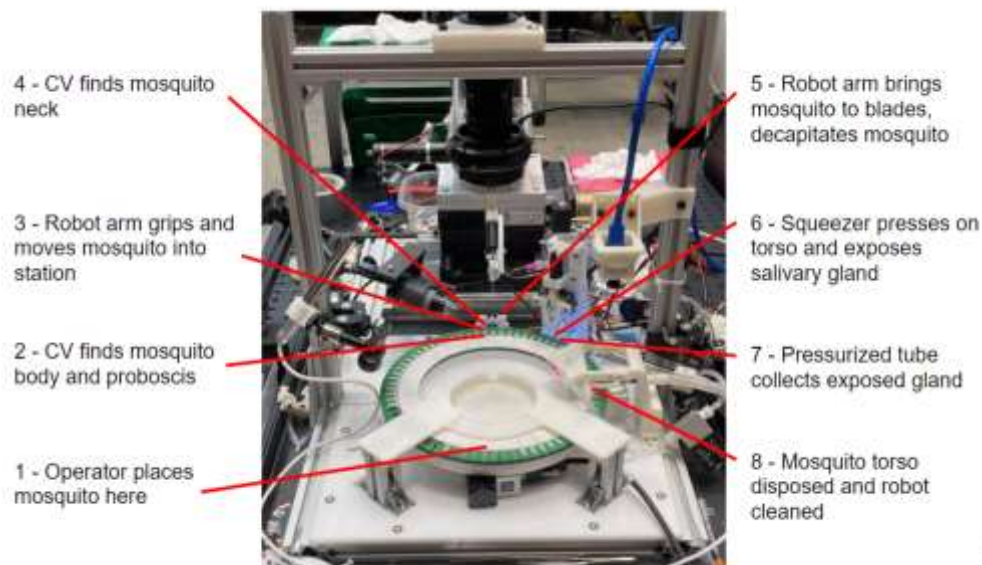


Figure 1: Current robot design, with steps of mosquito manipulation process

This goal of this project is to streamline calibration routines and create a well-integrated single calibration package that can handle most calibration tasks automatically. This project also aims to rethink how the robot workspace and its planned paths are defined, and implement a solution that can be maintained easier by human developers.

## Project Technical Approach

The robot's calibration tasks can generally be divided into three major components:

- Robot homing (robot encoder reset)
- Robot tool path (path planning with respect to workspace)
- Handeye calibration (camera to robot arm)

For the **robot homing calibration** task, we plan on using a vision based approach to home the robot to a known calibration point in 3D space. Using two cameras that can see both the robot tool tip and a fixed landmark object simultaneously, we can use the two 2D projections to incrementally minimize the pixel difference between the tool tip and the calibration landmark in both images. The robot can then converge on the 3D point in space, and we would set this point as the robot's home position. By collaborating with project colleagues, we can train a neural network to automate the computer vision components.

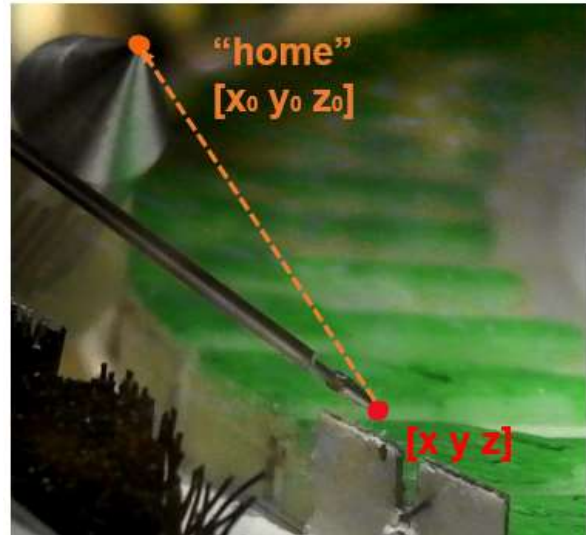


Figure 2: Robot homing in one camera view

For the **robot tool path calibration** task, we plan on designing and implementing a calibration graph that defines the spatial relationship between robot path waypoints and robot hardware. The graph will be built on the relative spatial relationships of waypoints, such that any calibrated adjustment in some hardware parameter would propagate further down the graph and update any dependent nodes' coordinates. This graph can be stored as a human-readable config file for operators to inspect and edit when necessary.

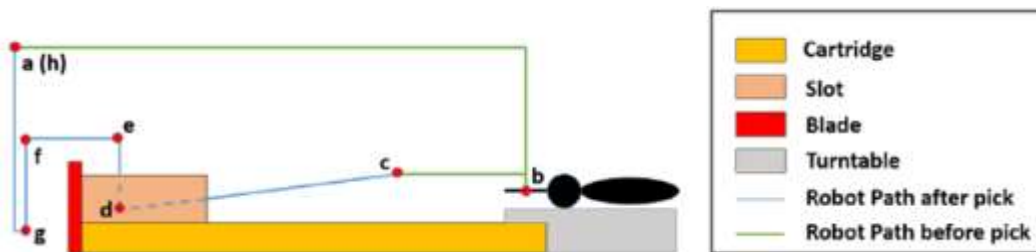


Figure 3: An example robot tool path to perform mosquito placement for decapitation

To integrate into the robot's system workflow, the graph will have its own ROS node as an API endpoint, where other components can provide input parameters and query for robot waypoints.

For the **hand-eye calibration** task, since there is already an existing calibration procedure that can handle the bulk of the calibration, our main objective would be to package the script such that it can be integrated into the ROS framework for the robot.

Ultimately, to develop a full calibration procedure with all subcomponents mentioned above, we would develop an operator-centered GUI using ROS's rqt that can provide the supervising operator control over the procedure as well as pertinent calibration information.

## **Deliverables**

### **Minimum**

- Streamlined calibration components integrated with ROS
- Prototype implementation of calibration graph
- Significant progress with development of robot homing calibration procedures
- Documentation

### **Expected (continued from minimum)**

- A single calibration workflow & GUI that covers all calibration tasks
- 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
- Updated calibration workflow that incorporates Sanaria feedback

## **Project Timeline & Milestones**

### **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, start debug/enhancement period

### **Late April**

- Package and finalize deliverables, develop in depth documentation
- Prepare final poster presentation

### **May**

- Course-end evaluations and poster presentations.

Item	Expected Completion	Status	Progress (As of 02/27/2022)
Research and determine technical approaches	02/28/2022	Completed	100%
Update and cleanup existing calibration procedures (Handeye calibration, etc.)	03/07/2022	In Progress	30%
Prototype implementation of Calibration GUI	03/31/2022	Not Started	0%
Prototype implementation of Robot homing	03/31/2022	In Progress	50%
Prototype implementation of Calibration tree	03/31/2022	In Progress	50%
System verification testing on hardware	04/15/2022	Not Started	0%
Modularize components, integrate into calibration workflow	04/20/2022	Not Started	0%
System development and deployment documentation	04/30/2022	Not Started	0%
Solicit user input on system design	04/15/2022	Not Started	0%
Final poster presentation	05/04/2022	Not Started	0%

## Dependencies

Here is a list of dependencies identified so far, as well as plans for resolving:

### 1. Availability of robot station and robot core components (arm, cameras, etc.)

Much of the project depends on robot hardware, and thus would be difficult to conduct integration testing, data collection, etc. without access to the actual robot. This can be caused by complete hardware failure, or scheduling conflicts with other project teams that require the robot.

**Plan for resolution:** Many of the project's subcomponents can be drafted and developed substantially remotely or even in isolated ROS development environments (such as my own laptop), such as the GUI, calibration graph, and computer vision integration. This allows us to reach a significant portion of the deliverables even without the robot station.

### 2. Frequency of hardware changes on robot

While the calibration packages are built to mitigate the effects of frequent hardware changes on development workflow by reducing effort required for recalibration, as the packages are being developed, if hardware changes are too frequent, it may affect our ability to collect meaningful data and conduct repeatable integration testing.

**Plan for resolution:** The same plan as dependency 1. We will also coordinate with the hardware teams as much as possible with schedules and frequent communication to avoid conflicts.

3. **Neural network for tooltip detection during robot homing**  
(Resolved as of 02/27/2022)

If the development of the neural network used for tooltip detection is unexpected delayed, we will not be able to use it during robot homing. The procedure will no longer be completely automated.

**Plan for resolution:** To eliminate the dependency of the robot homing procedure on vision, we can deploy a stopgap manual solution that asks an operator to manually label tooltip and target positions in images during the procedure, essentially replacing the CV algorithm.

## Management Plan

The project team will meet weekly on Fridays, as well as weekly with the entire lab group on Mondays.

Communication will be mainly over email, and in-person discussions in lab as necessary.

Developed code will be maintained on GitLab

Documentation, slides, collected data, images, etc. will be stored on Microsoft Teams & the 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 15<sup>th</sup> 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.