Group 03: Paper Review

Robot System Control for Automating Mosquito Microdissection

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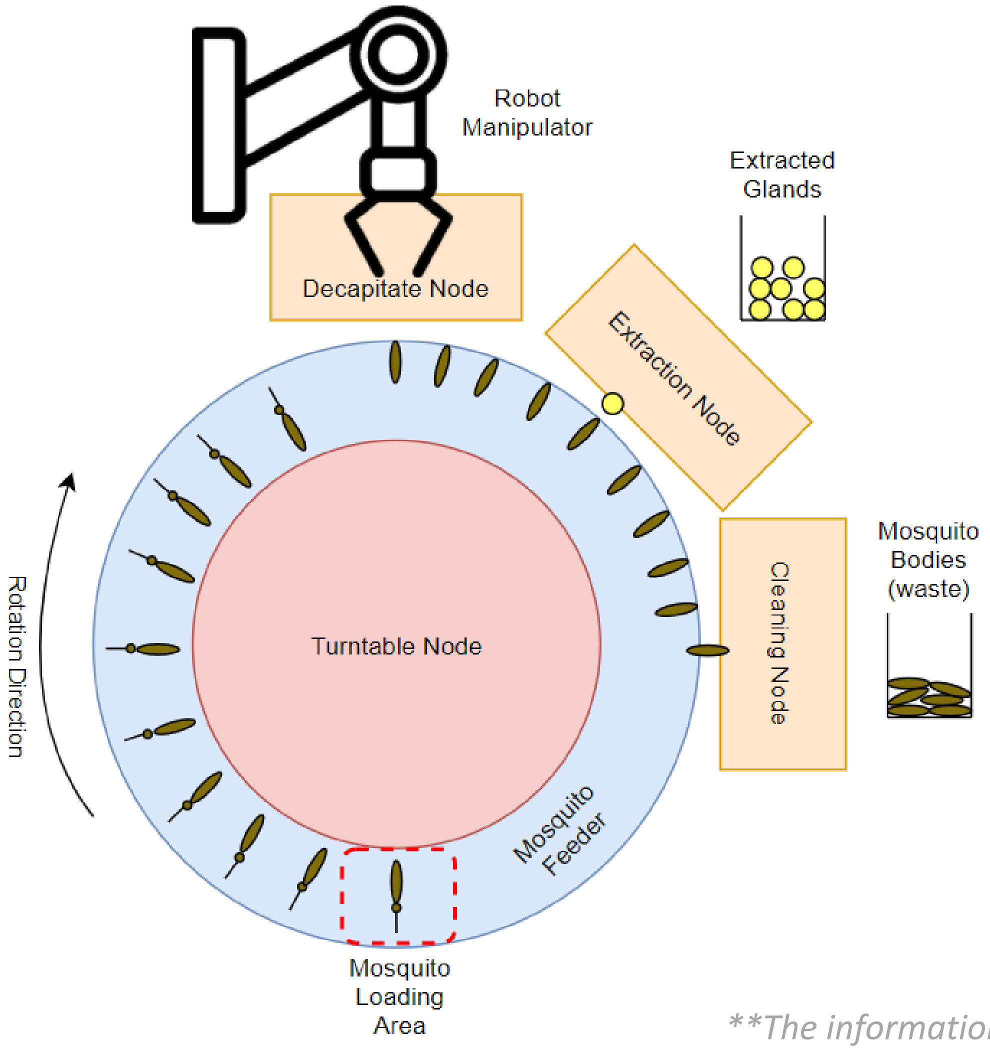
Current System

Project Summary

- **Problem:** Sanaria needs to increase the production rate of *Plasmodium falciparum* sporozoits (PfSPZ) from infected mosquito glands to help produce a promising malaria vaccine.
- **Overall Goal:** Automate the gland dissection process using a robot system. Our goal is to dissect 600 mosquitoes per hour (mph).
- **CIS Project Goal:** To develop a robot system control algorithm that introduces parallel processes, error checking, and error recovery.

Current System



Main Concept: Nodes surrounding a turntable

Components:

- Turntable Node – convey mosquitoes from node to node.
- Robot & Decapitate Node – drag mosquito between blades and decapitate.
- Extraction Node – squeeze mosquito to extrude salivary glands, extract glands.
- Cleaning Node – clean of mosquito body.

Paper Summary

** All media used in this section are from the paper **

Paper Selection Motivation

Li, W., He, Z., Vora, P., Wang, Y., Vagvolgyi, B., Leonard, S., Goodridge, A., Iordachita, I., Hoffman, S., Chakravarty, S., & Taylor, R. (in press). Automated Mosquito Salivary Gland Extractor for PfSPZ-based Malaria Vaccine Production. *2021 IEEE International Conference on Robotics and Automation (ICRA)*.

- Previous iteration of our current system.
- Discussed the design of a **serial robot system** for mosquito dissection which can analyze to inform the design of our parallel system.
- Discussed a simulator which would be useful for testing.
- There are few papers in this area of research, this paper is the most relevant.

Introduction & Background

Key Concepts:

- Malaria is significant
  - 228 million cases; 405,000 deaths in 2018
  - Vaccines are a long term solution to curb spread
  - Sporozoite lies in salivary glands.
- Sanaria is working on increasing production
  - Manual gland extraction is a labor intensive step (290 mph)
  - Semi-autonomous system (sAMMS) increases extraction speed (450 mph)

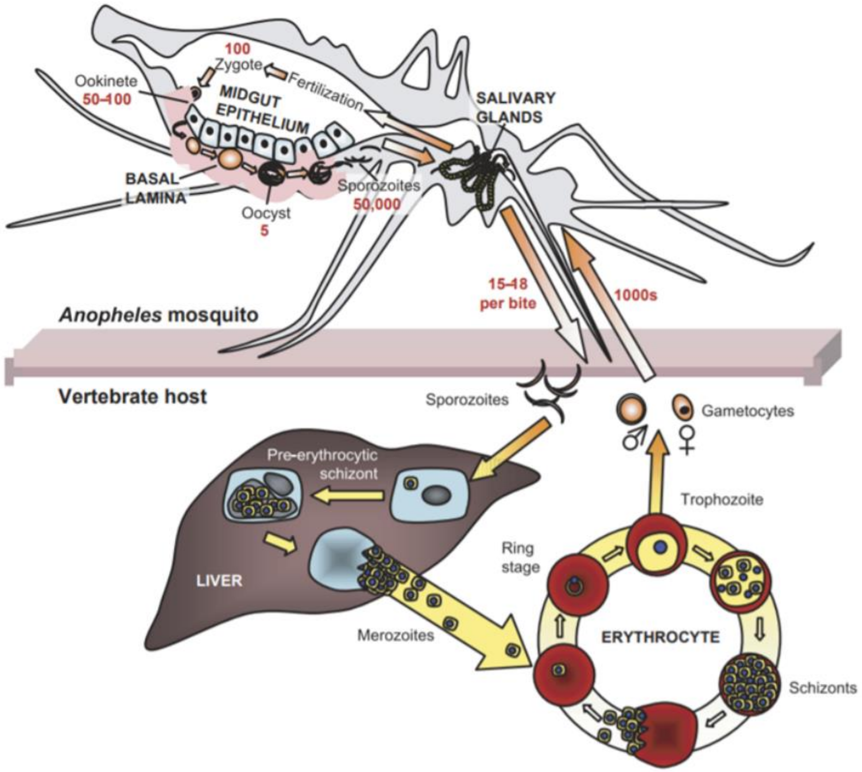


Figure 1. Malaria Life Cycle

System Overview

Automation Procedure:

1. Mosquito placed in loading area
2. Turntable introduces mosquito in front of robot
3. Robot places mosquito on stage
4. Decapitate the mosquito
5. Move stage to squeezing station
6. Squeeze the mosquito body to extrude saliva gland.

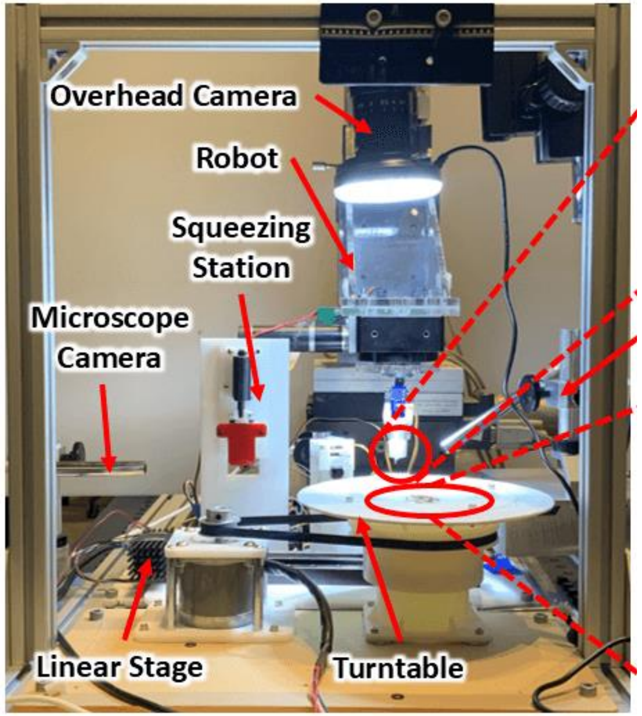


Figure 2. Actual System

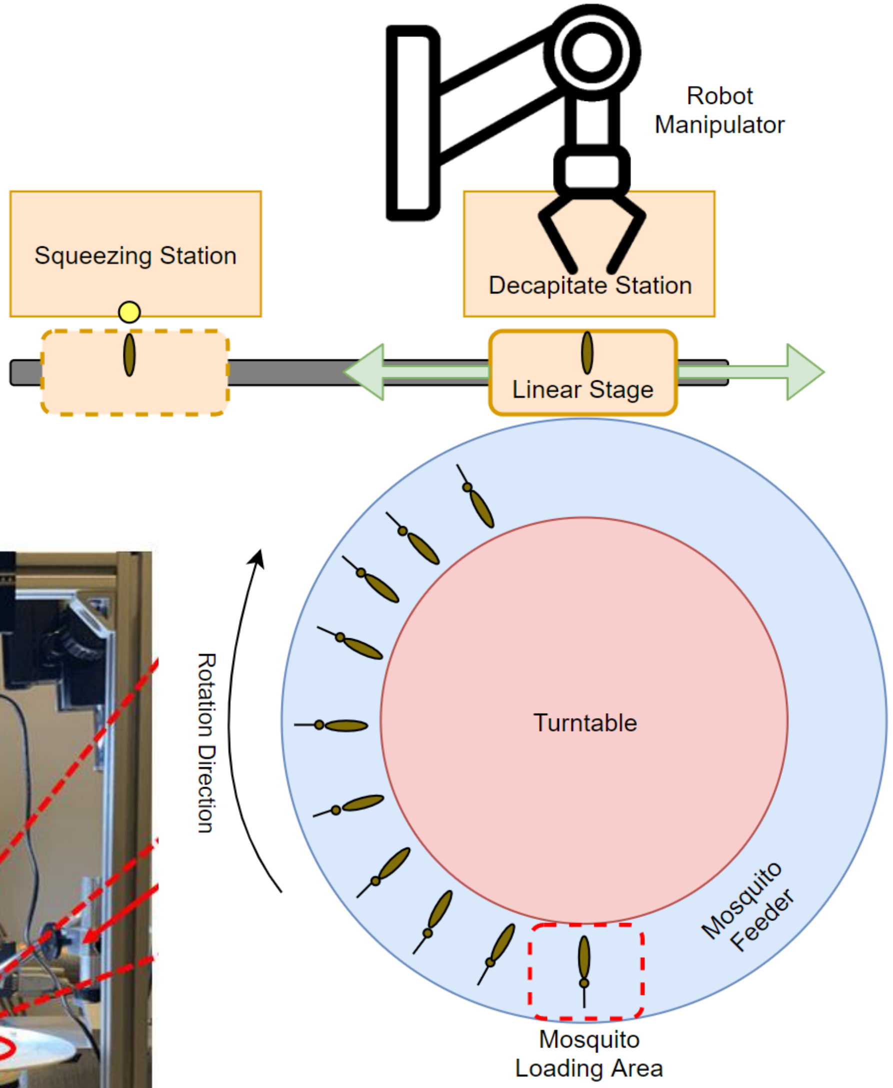
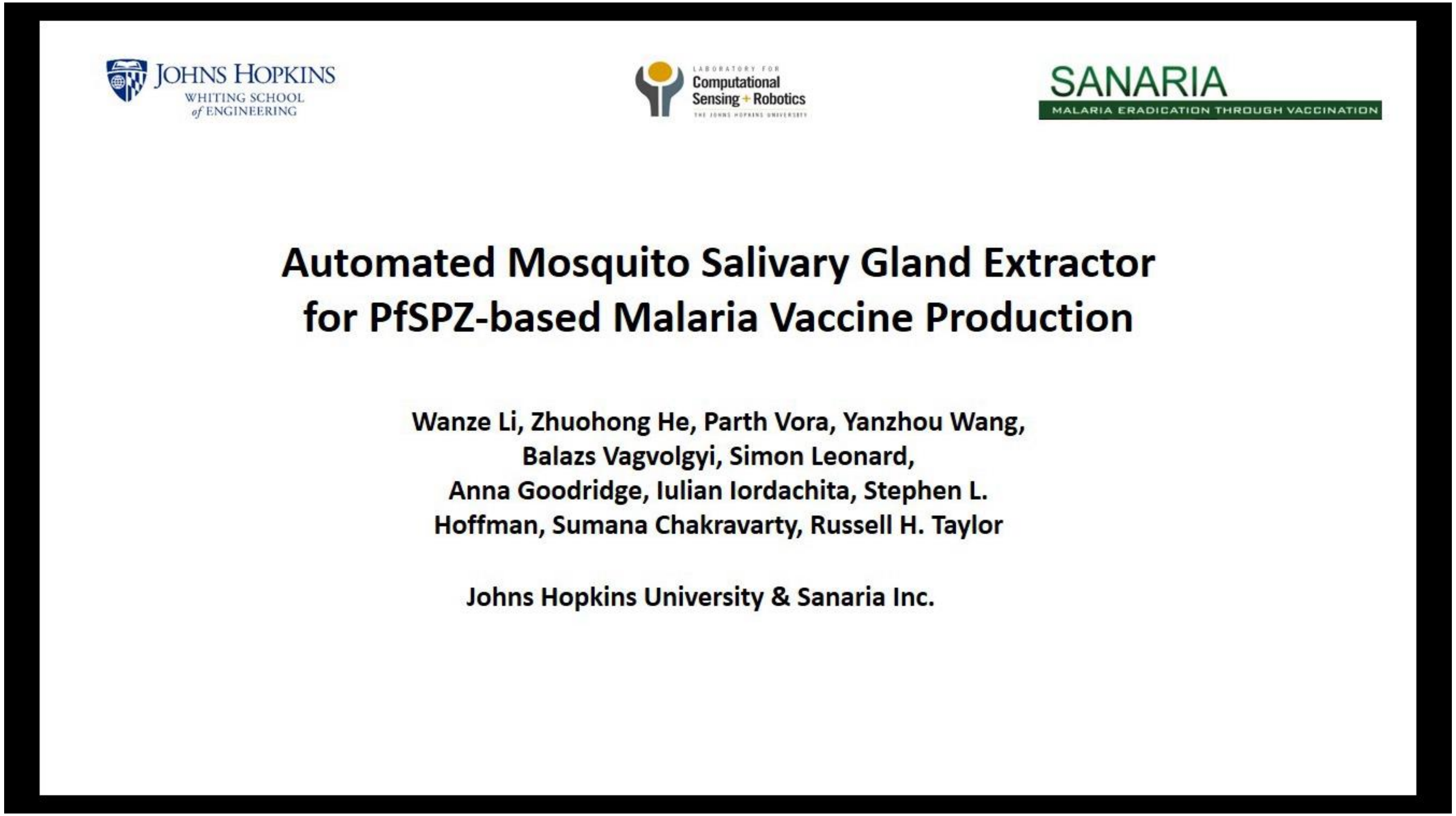


Figure 3. System Diagram

**The information in this presentation is strictly confidential*

System Overview (Video)



Automation Procedure (Video)

Software Design Specifics

- The controller is designed using Robot Operating System (ROS).
- Communication occurs on topics.
- ROS ActionLib client-service paradigm allow for robust communication and connection to simulation.

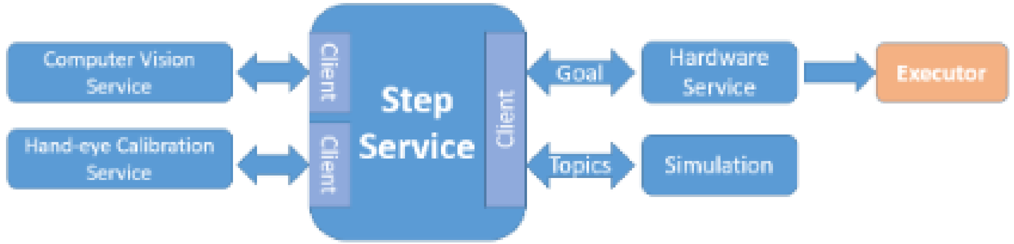


Figure 4. Action Client/Service

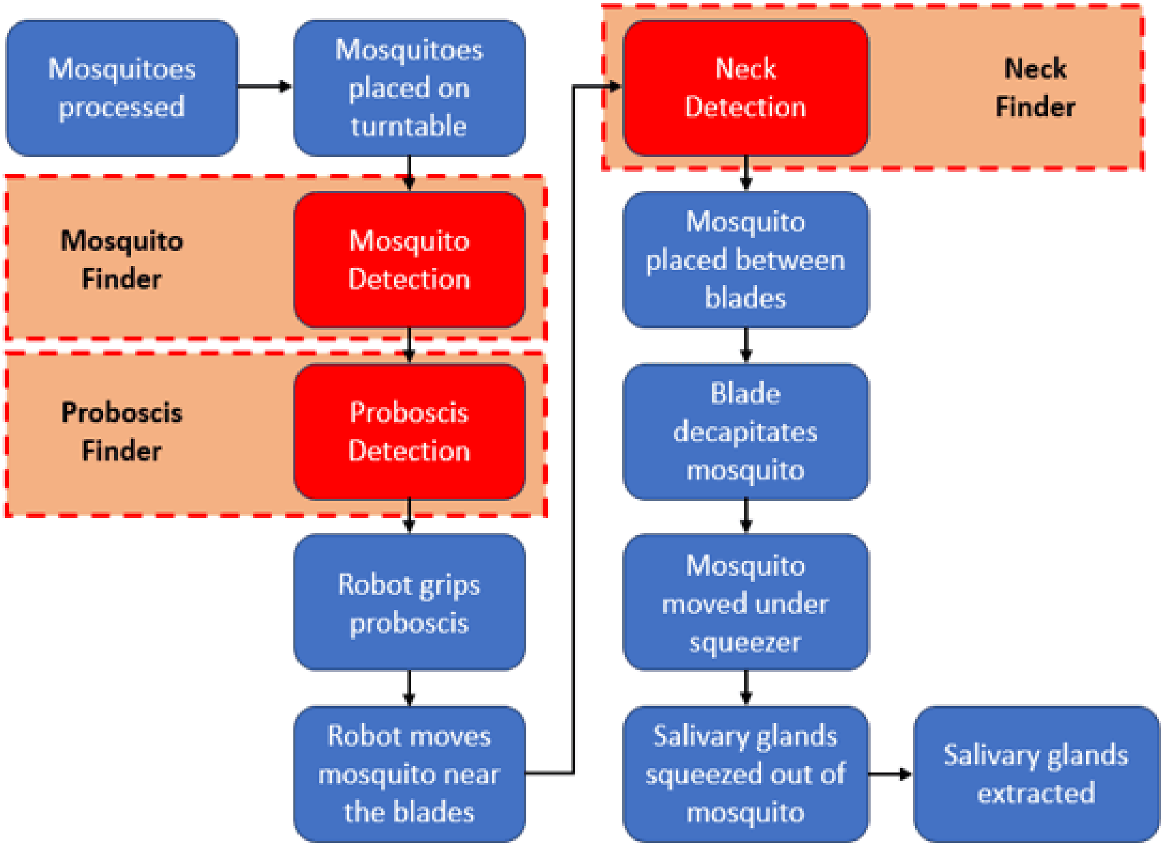


Figure 5. Serial Controller Diagram

Simulation

- Simulation of each component is visualized using the Robot Visualization tool (RViz)
- Each simulation node acts as another server which listens to controller client commands.
- GUI built using RQt.
- Trajectory Generator nodes simulate the real robot physics

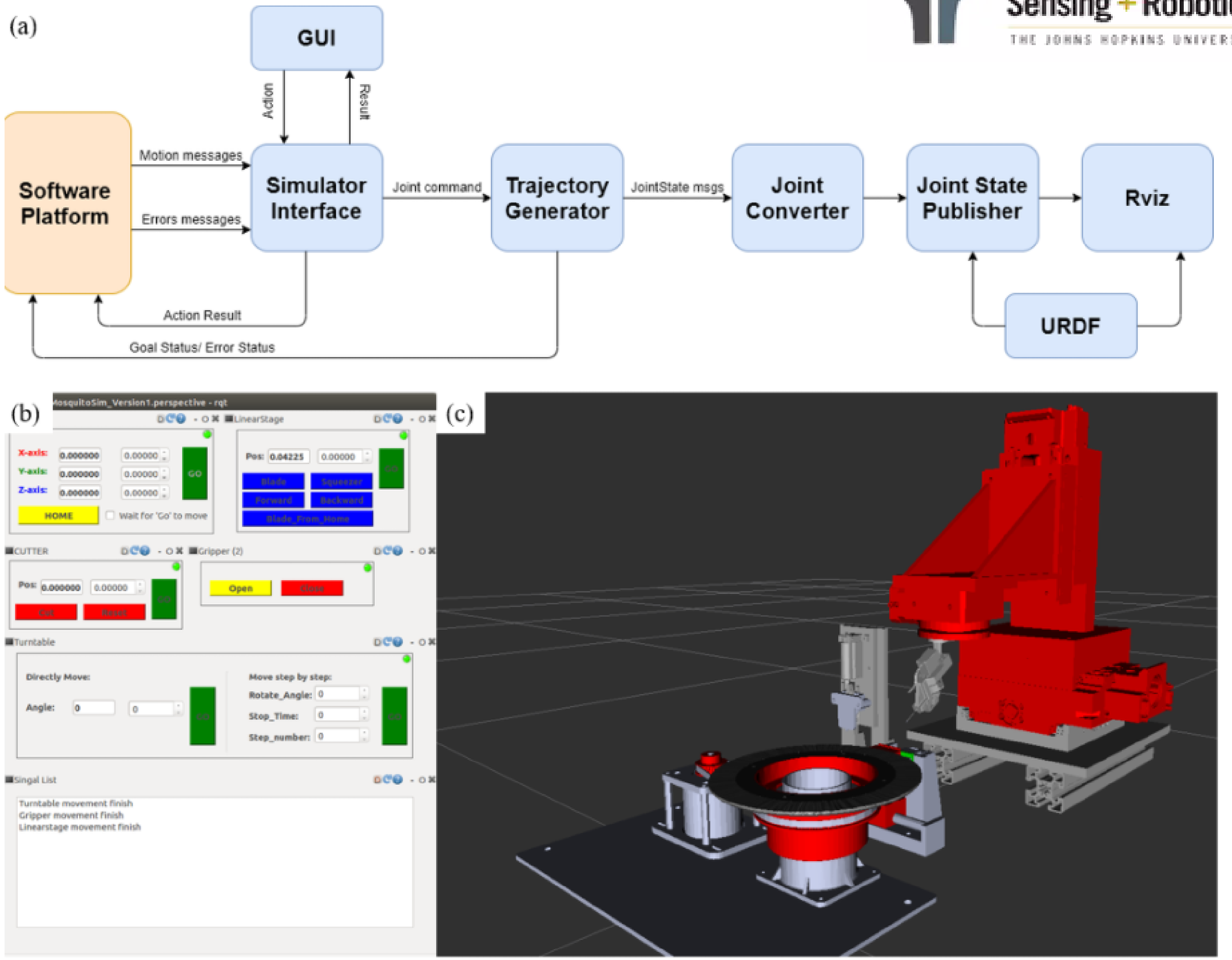


Figure 6. (a) Simulation ROS Architecture, (b) Simulation GUI, (c) RViz 3D Visualization

Results

- Experiments were conducted on 100 real mosquitoes to determine the success rate of each step in dissection.

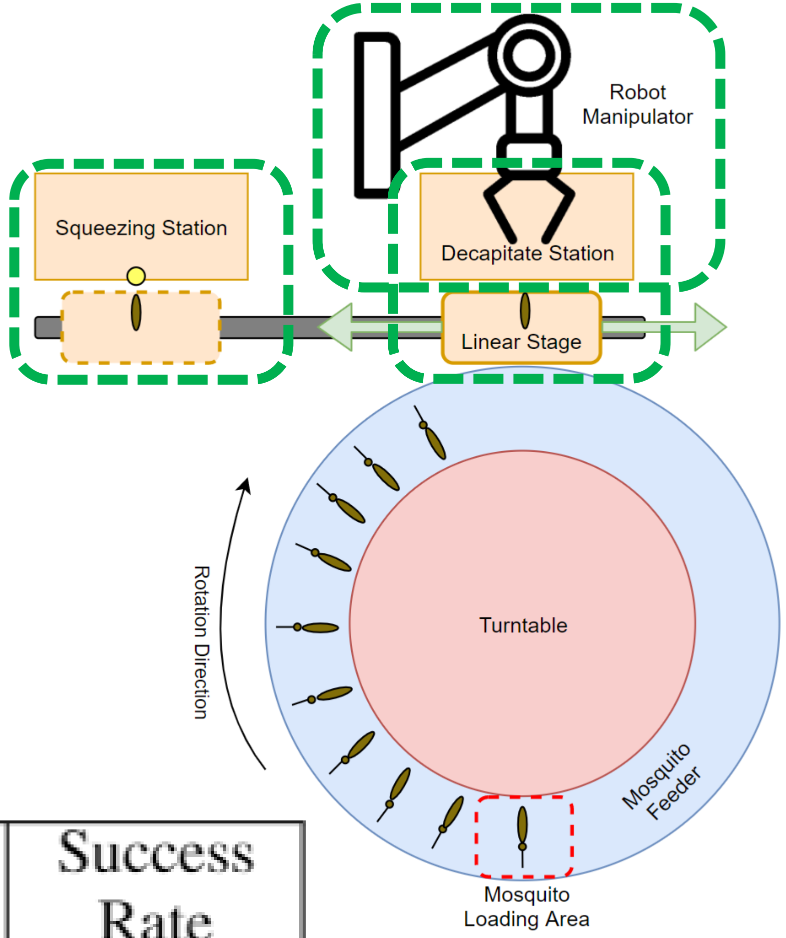


Table 1. Quantitative Evaluation Results

Procedure	Step	Success	Failure	Total	Success Rate
MPPD	Pick-Place	93	7	100	93%
	Decapitate	93	0	93	100%
Gland Extract	Squeezing	81	12	93	87.1%
Overall		81	19	100	81%

Discussion

- The system produced an overall success rate of 81% demonstrating the potential for automated mosquito dissection.
- Decapitate had strong performance (100%)
- Pick-and-Place (93%) and Gland Extraction (87.1%) are the weakest which could be improved by redesigning, improving CV, or adding error recovery.
- Stiff mosquitoes caused many failures. Need improved method to keep mosquitoes fresh and nimble.
- Still need gland storage and automated cleaning stations.

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Discussion

Figure 7. Experiment Timing Analysis (** this figure is not included in paper)

Action	Time	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57
Pick & Move	6																			
Place & Cut	3																			
Home Robot	1																			
Move under Squeezer	20																			
Gland extrusion	3																			
Home cartridge	27																			

Removing Turntable Time (47s):

$$\frac{1m}{(60s-47s)} \times \frac{3600s}{1hr} \times 0.81 = 224.3mph \sim 290mph$$

- Adding parallelization and error recovery, could result in even faster speeds.

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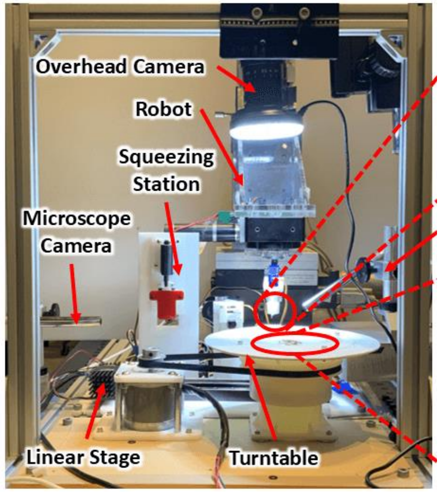
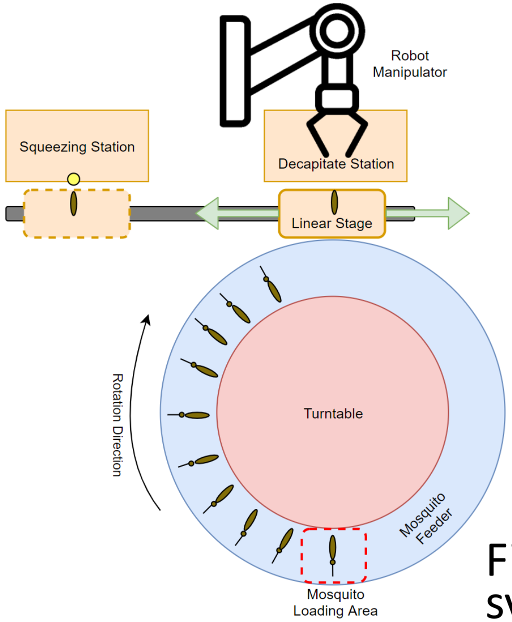
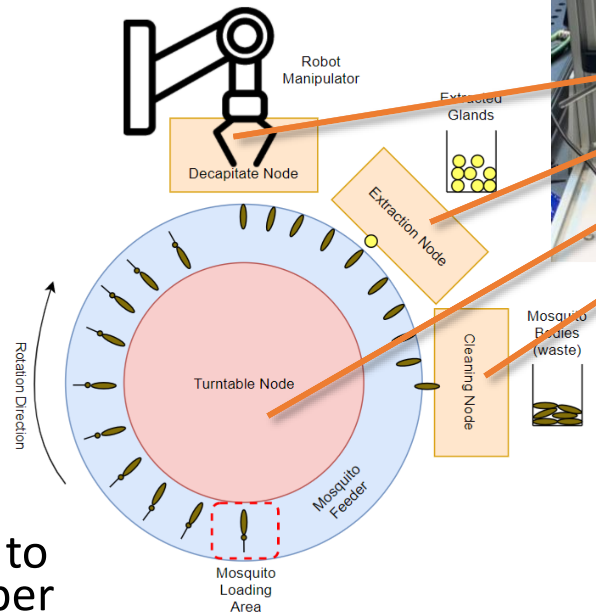
Key Lessons

- The stations are all effective, but can be improved from both the hardware and controller aspects.
- System centered around turntable could improve times by removing the time of the linear stage.
- Error recovery is most needed on the pick-n-place and extraction stations.
- Parallelization of stations could further improve the throughput rate.
- ActionLib Client-Server architecture is effective for our controller.
- The RViz simulation is a great resource for debugging and development.







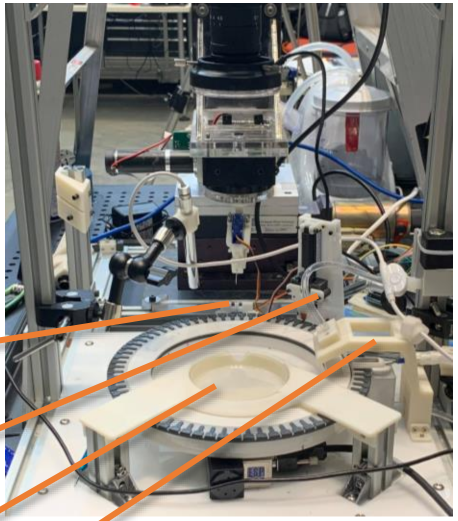


Figure 8. Improvements to system after work in paper

References

[1] Li, W., He, Z., Vora, P., Wang, Y., Vagvolgyi, B., Leonard, S., Goodridge, A., Iordachita, I., Hoffman, S., Chakravarty, S., & Taylor, R. (in press). Automated Mosquito Salivary Gland Extractor for PfSPZ-based Malaria Vaccine Production. *2021 IEEE International Conference on Robotics and Automation (ICRA)*.

[2] M. Schrum, A. Canezin, S. Chakravarty, M. Laskowski, S. Comert, Y. Sevimli, G. S. Chirikjian, S. L. Hoffman, and R. H. Taylor, "An efficient production process for extracting salivary glands from mosquitoes," 2019, arXiv:1903.02532 [q-bio.QM]. [Online]. Available: https://arxiv.org/abs/1903.02532

Thank You