

CIS II Seminar:

## “MOSQUITO PICK-AND-PLACE: AUTOMATING A KEY STEP IN PFSPZ-BASED MALARIA VACCINE PRODUCTION”

AUTHORS: HENRY PHALEN, PRASAD VAGDARGI, MICHAEL POZIN, SUMANA CHAKRAVARTY, GREGORY S. CHIRIKJIAN, FELLOW, IEEE, IULIAN IORDACHITA, SENIOR MEMBER, IEEE AND RUSSELL H. TAYLOR, LIFE FELLOW, IEEE

*Project 5: Mosquito Vision - Guidance for Automated Robotic Mosquito Salivary Gland Extraction*

Group: **Akash Chaurasia**, Alan Lai, Parth Vora

Mentors: Balazs Vagvolgyi, Dr. Russ Taylor

# Project Overview

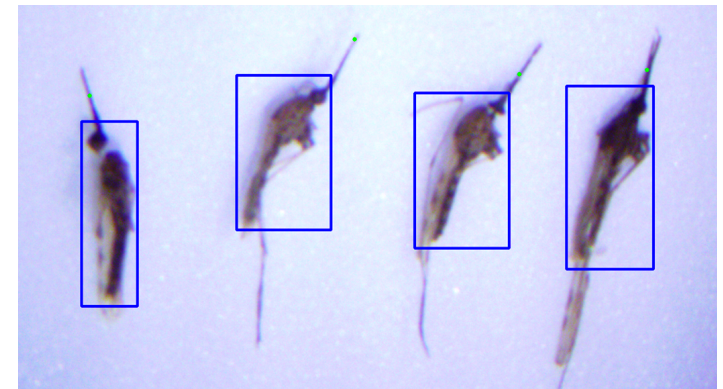
*Creating a **vision system** to guide a semi-autonomous robot for the **extraction of mosquito salivary glands**, ultimately to be used in the production of a **live malaria vaccine***

## Background:

- Sanaria, Inc. (Rockville, MD) has developed a live vaccine for malaria shown to be 100% clinically effective in trials
- Extracting the salivary glands of mosquitos is essential in vaccine production – currently done manually
- Mass-production of this vaccine would ideally involve automation to expedite the gland extraction process using a robot
- Previous/ongoing work on a robot system, on the path to partial autonomy

## Goals:

- Develop computer vision methods for:
  - Detecting mosquitos in workspace
  - Locating center of mosquito neck
  - Locating center of mosquito proboscis
- Software integration with robot system (ROS)
- Documentation of algorithms, usage, etc.
- Full system validation



*Mosquito detection & proboscis localization*

# Paper Selection

H. Phalen *et al.*, "Mosquito Pick-and-Place: Automating a Key Step in PfSPZ-based Malaria Vaccine Production," *2019 IEEE 15th International Conference on Automation Science and Engineering (CASE)*, Vancouver, BC, Canada, 2019, pp. 12-17.

- Our project focuses on the computer vision components of a **comprehensive robotic system**
- This paper evaluates a pivotal step of the robot-facilitated production: the pick-and-place method
- The proposed system is still very much representative of the current setup
  - Grasping
  - **Localization**
  - Placement
  - Decapitation
- The following authors are still part of the core group working on the system: Dr. Sumana Chakravarty, Dr. Iulian Iordachita, Dr. Russ Taylor

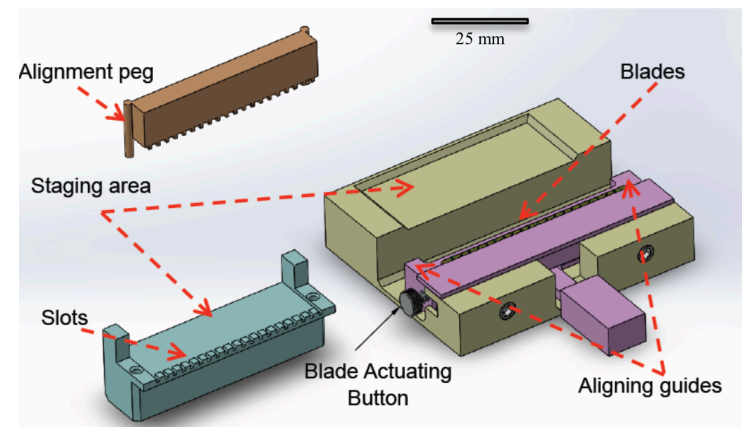
# Relevant Background

- Sanaria Plasmodium falciparum sporozoite-based vaccine (Sanaria® PfSPZ Vaccine) – 100% clinical efficacy in providing immunity against malaria
  - ~219 million individuals infected worldwide in 2017 (WHO)
  - Top 20 causes of death in adults & infants in 2016
- PfSPZ is extracted from the salivary glands of mosquitos
  - Extraction requires extensive training, manual process
- Previous work demonstrated efficacy of the sAMMS cartridge
  - ~2x mosquito throughput, shorter training period

## ***Automate loading of sAMMS?***

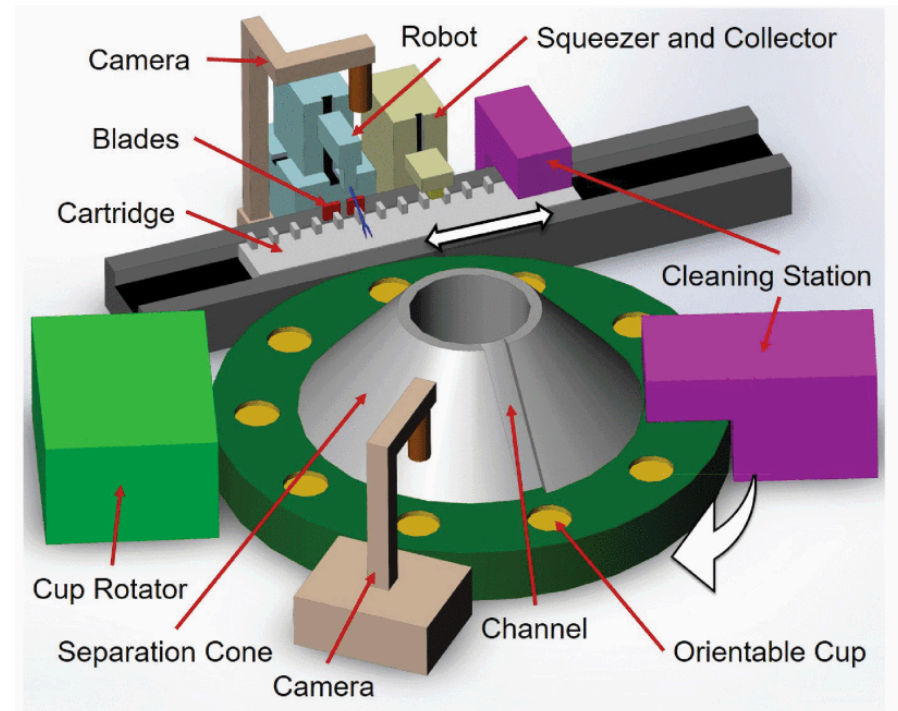
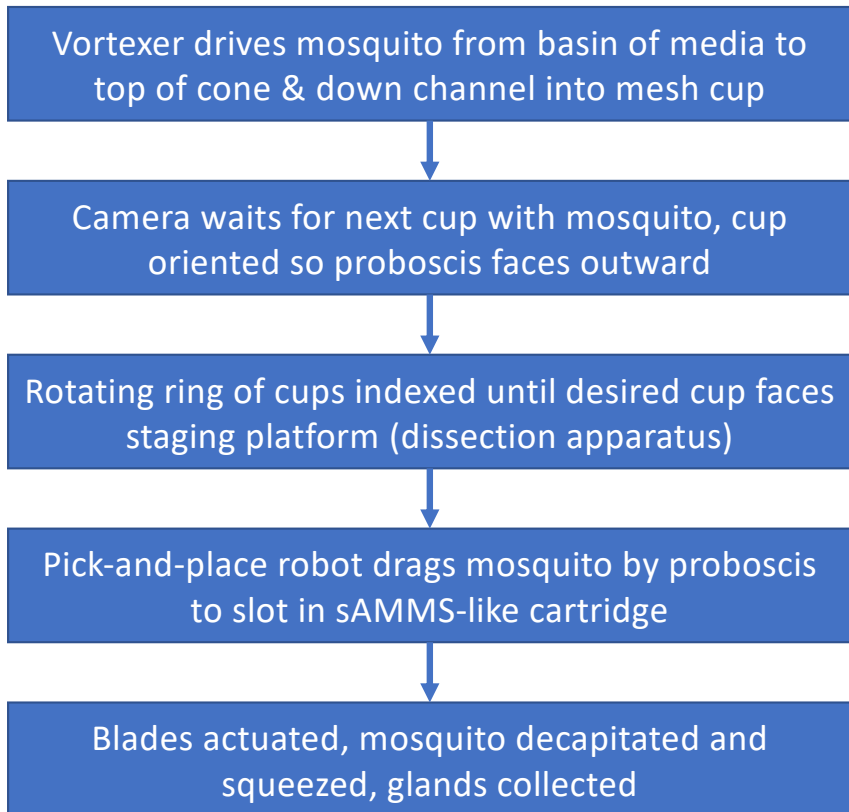
*100% success rate for grasping mosquitos*

*90% success rate for placing mosquito neck between blades*



sAMMS cartridge diagram, Schrum et. al [2]

# Methods: System Design

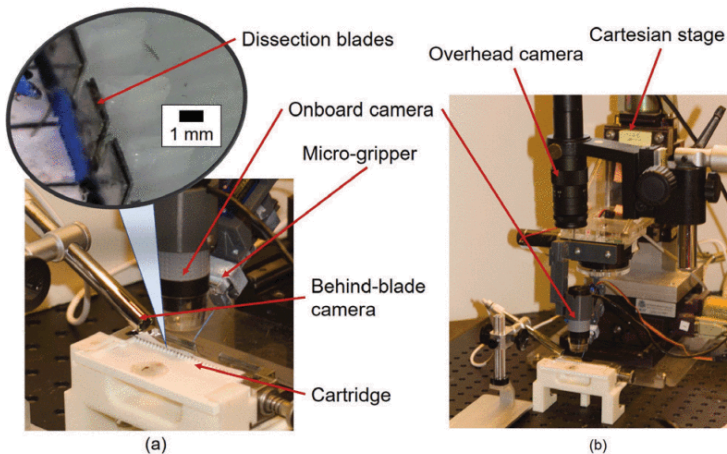


Concept diagram of automated dissection system, Phalen et. al. [1]

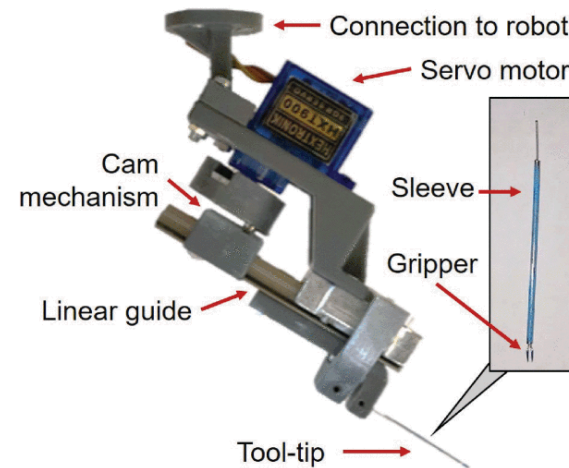
# Methods: System Requirements & Implementation

## Requirements:

- Neck placed between blades within 200  $\mu\text{m}$  (for optimal decapitation & gland extraction)
- Grasping must occur only on the proboscis (approximately 2.0 mm x 0.1 mm)
- The system must be able to adapt robot movements to variability in placement & anatomy



Experimental setup, Phalen et. al. [1]

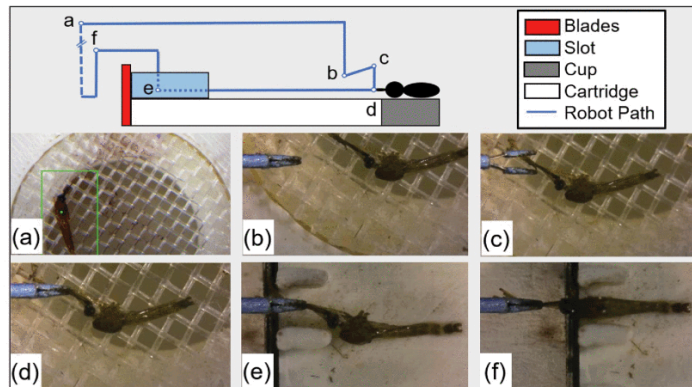


Micro-gripper mechanism, Phalen et. al. [1]

4 DOF linear stage robot, 12V DC servo motor in each axis,  
Positioning resolution = 10  $\mu\text{m}$ ; Galil microcontroller

Servo-driven cam  $\rightarrow$  close/open jaws  
Arduino & USB control

# Methods: Experimental Execution



Robot path and representative images, Phalen et. al. [1]

## Pick:

1. Mosquito manually placed in cup on cartridge
  - a) Proboscis within 45 degrees of facing blades
2. Centroid of mosquito located via overhead camera\*
3. Robot moves to 5 mm in front of centroid
4. Centroid of proboscis located via onboard camera\*
5. Gripper moves to centroid, lowers & grasps
6. Robot grabs mosquito towards blades
7. Onboard camera image capture (verification, grasping point localization)\*

## Calibration

- Tool tip relative to overhead camera frame
- Bernstein (4<sup>th</sup> order) to fit between robot encoder & camera coordinates
  - Accounts for radial & aspheric lens distortions

50 non-infected mosquitos (stored in PBS for 1 day post-sacrifice)

Unless specified, all robot movements are at a speed of 12 mm/s in each axis

## Place:

1. Head-to-tooltip offset calculated\*
2. Robot raises head & advances a set distance plus calculated offset
3. Robot lowers neck between blades (2.5 mm/s)
4. Blades manually actuated

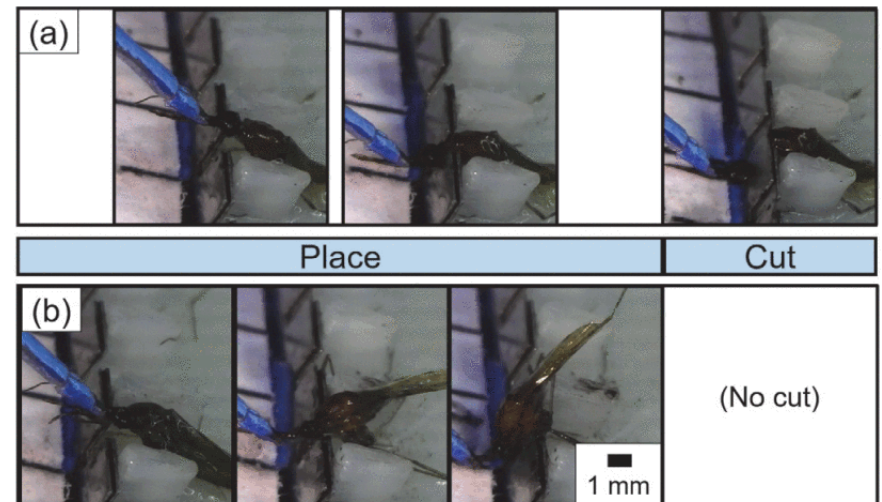
\* = vision guidance steps

# Results & Discussion

- **Pick: 50/50 (100%)** of mosquitos successfully grasped at second vision check
- **Place: 45/50 (90%)** of mosquitos placed with neck properly aligned
  - Consistent failure case, indeterminate cause

## Author Conclusions:

- Micro-gripper mechanism robust for given task
- Vision system enables adaptation to positioning & anatomical variability
- **Overall 90% success rate is encouraging**
- Place step requires more accuracy & precision
- Future work will improve vision for head-to-tooltip offset calculation
- Further investigation required for angle of image capture
- Potential improvement through mechanical design to guide mosquito in slot
- **Future work could lead to throughput of ~700 mosquitos/hr**



*Demonstration of mosquito placement, Phalen et. al. [1]*

# Paper Assessment

**Overall:** foundational work outlining an automated process for salivary gland extraction, as well as demonstration of the efficacy of the pick-and-place method.

- Very relevant to our goals:
  - Leveraging pick-and-place method, extremely similar mechanical setup
  - Detecting mosquitos
  - Locating mosquito proboscis, head
- Identifies areas for improvement
  - Tool-to-\_\_\_\_\_ offset?

## Positives:

- Clear definition of success/failure cases
- Clear justification of experiment
- Good placement of research in context of overall project
- Strong results: complex system with many components & interactions

## Negatives:

- Poor description of vision methods used beyond calibration
- Vague description of system configuration & implementation
- Room for granularity/further analysis of success cases
- Unclear determination of preprogrammed/baseline positions

# Future Steps

Completed work (after publication):

- Implementation of automated bladed actuation
- Replacement of vortexer/basin/channel/mesh cups with manual placement and rotating turntable

Ongoing work:

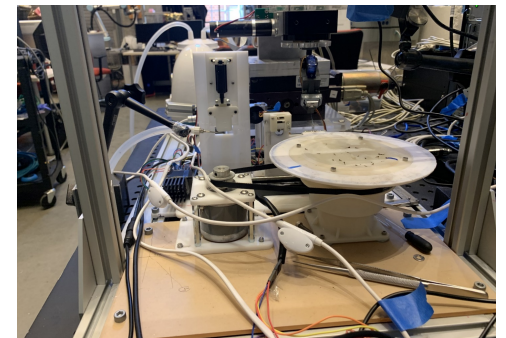
- Optimization of placement
- Improvements on vision algorithms (proboscis & neck localization, orientation detection)
  - Speed
  - Accuracy (to be quantified)
  - Neck localization (for offset)



*Squeezing & gland collection mechanisms*



*Demonstration of automated pick & drag  
(new vision algorithms)*



*Overall setup with new turntable*

# References

- [1] H. Phalen *et al.*, "Mosquito Pick-and-Place: Automating a Key Step in PfSPZ-based Malaria Vaccine Production," *2019 IEEE 15th International Conference on Automation Science and Engineering (CASE)*, Vancouver, BC, Canada, 2019, pp. 12-17.
- [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," arXiv:1903.02532, 2019

# Thank You! Questions?

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