Automation of Mosquito Dissection for Malaria Vaccine Production

Computer Integrated Surgery II
February 26, 2019

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Mentors:
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Background

- Working as part of larger LCSR effort
- Small Business Innovation Research (SBIR) grant from NIH with Sanaria Inc.
- Sanaria has developed a methodology to produce a **malaria vaccine**
- Malaria is spread by a parasite (**Plasmodium falciparum**) that grows in the salivary glands of mosquitoes (**anopheles**)

**SANARIA**

**MALARIA ERADICATION THROUGH VACCINATION**

Confidential
Clinical Motivation

• Malaria is a **global** health problem

• Estimated malaria deaths 2015:
  • 438,000\(^1\)
  • 666,000\(^2\)
  • 730,500\(^3\)

• Estimated clinical cases 2015:
  • 214,000,000\(^1\)

• >$12B GDP loss in Africa alone\(^{1,4}\)

From WHO World Malaria Report 2016

The Project

- To develop the vaccine, mosquitoes are bred, infected, dissected, and their salivary glands harvested and purified.
- The harvested parasite sporozoites become the vaccine agent.

Current Dissection Procedure:

- Major bottleneck to vaccine production:
  - 5-6 mosquitoes per minute after several months of training.
Prior Work

• A team from LCSR created a mechanical system to increase efficiency
• Training time reduced to ~1.5 weeks

1. Place mosquito neck between a pair of blades
2. Squeeze out the salivary gland (and some “guts”)
An Automated Approach

• Our goal is to develop an automated mosquito dissection system

Staged Mosquitoes → Dissection System → Salivary glands

Within a Larger System:

1. Mosquito separation
2. Mosquito pick-and-place
3. Mosquito dissection
4. Mosquito recognition (throughout)
Technical Approach: Outline

1. Minor changes to robotic pick-and-place assembly
   ○ Mosquito alignment slot geometry

2. Development of current dissection system
   ○ Redesign of downstream processes
   ○ Verification testing

3. Multi-component integration
   ○ Timing & Code
   ○ Systems out of Control (Vision & Feeding/Staging System)

4. Rotary Stage Design
   ○ Develop rotating cartridge design for integration with pre-existing and developed modules
Robot Setup

Decapitation blades

Behind-blade camera

Micro-gripper

Cartridge

Overhead camera

Cartesian stage
1. Changes to Pick-and-Place System

- Robot can take an image location, navigate to the site, grasp a mosquito, position between blades
- Bernstein polynomial calibration
- No downstream processing attempted
- ~85% accuracy - hope to improve this
  - Minor changes to mechanical geometry
  - Better use of information from vision
2. Development of current dissection system

- Redesign and test downstream processes
  1. Cutting 😊
  2. Squeezing 😞
  3. Gland Collection 😞
  4. Wash 😞
3. Multi-system integration

- Multi-component timing
  - Single time bottleneck (most likely robot motion)
  - Simultaneous actuation at multiple levels of system

- Code
  - High-level system control
  - ROS topics
  - Serial communication with microcontrollers

- Integration with systems out of our control
  - Vision, mosquito feeding/staging
4. Rotary Stage Design

- Linear system will provide proof-of-concept of modules
- Rotary system will be developed to allow for a more streamlined process
Milestones

- **2/26**: Physical Prototype of Gland Collection Apparatus
  - **MP AC 3/4**

- **3/12**: High-level Code for Robot/Dissector Integration Completed
  - **HP 3/12**

- **3/18**: Dissector Installed on Robot Setup
  - **MP AC 3/18**

- **3/26**: Results from Preliminary Integration Testing Completed
  - **HP 3/26**

- **4/9**: Preliminary Testing Report
  - **4/1**

- **4/10**: Implement Mechanical Changes, Finalize Rotary Design
  - **AC MP 4/10**

- **4/15**: Test with 100+ Mosquitoes
  - **HP 4/23**

- **5/7**: Formal report on Vision System Integration and Systems Level Approach
  - **5/7**

- **5/7**: Vision System Integration
  - **HP 4/29**

**Responsible Member’s Initials**

- **Key deliverable**
<table>
<thead>
<tr>
<th>MIN</th>
<th>03/26/19</th>
<th>Video of a mosquito processed from presentation to body disposal, specifically: Presentation → Pick &amp; Place → Decapitation → Squeeze → Gland Collection → Body Disposal</th>
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| IDEAL     | 04/23/19 | Written report detailing system integration (no vision), automated dissection of 50+ mosquitoes  
Written report of design concept of rotary stage |
| MAX       | 05/07/19 | Written report on system integration (with vision), automated dissection of 100+  
Physical prototype of rotary stage concept |
## Dependencies

| Dependency                                      | Solution                                                        | Date Expected | Date Required | Mitigation                                                                 |
|-------------------------------------------------|                                                               |               |               |                                                                            |
| Access to shared setup, computer, robot in Robotorium | Coordinate with collaborators                                | 2/26          | 2/28          | Perform testing in off-hours                                             |
| Access to Lab Pod, JH Box (Alex)                 | Ask Dr. Taylor for Access                                      | 2/28          | 2/28          | N/A                                                                        |
| Access to mosquitos (weekly basis)               | Email colleagues and Sanaria to coordinate pickup              | Weekly        | Weekly        | No testing that week, or unofficial testing with old mosq's or those in ethanol |
| Interface with computer vision system            | Rely on collaborators to continue development                   | 3/15          | 4/23          | Continue to use manual user-click commands                               |
| Upstream mosquito staging system                 | Rely on collaborators to continue development                   | 4/1           | 4/23          | Dissection system can be demonstrated with human-staged mosquitoes       |
| Money for mechanical development (e.g new stage, fabrication costs, etc.) | Ask mentors as needed - grant has funding                     | As needed     | As needed     | Use what resources are available                                          |
| Continued functionality of recently redesigned micro gripper | Rely on collaborators to continue ongoing improvements     | 2/26          | 2/28          | Complete redesign ourselves, possibly adjust project goals                |
Management Plan

Project Lead: Henry

Group Meetings: Monday Noon - 1PM, Friday Noon - 3PM

➢ Robot control, high-level code, integration: Henry
➢ Downstream dissection: Michael & Alex
➢ 2nd generation system design: Alex

Organizational Items:
● Weekly meetings with mentors and collaborators (Mondays 9-10AM)
● Any code stored in current project private Git repo
● Communication via Slack (Instant Messaging) and email
● All documentation stored in project JH Box and on course website
Questions?