Project 6: Vision Guided Mosquito Dissection for the Production of Malaria Vaccine

Goal
To implement and design effective computer vision algorithms for the autonomous mosquito dissection robot using classical and deep learning-based methods.

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Relevance/Importance:
Malaria accounted for 229 million cases and 409,000 deaths worldwide as of 2019. It is an understatement to say that there is a need for vaccine development and deployment. Sanaria Inc. has found groundbreaking results and progress in a malaria vaccine, which uses mosquito salivary glands for research and synthesis. However, these glands are difficult to extract manually and often require high skill and precision, not to mention it also being time consuming. As a result, there is a need for an automated system that can mass-extract salivary glands from mosquitos. There has been a collaboration between JHU CIIS and Sanaria Inc. in order to produce a robotic system to complete this task.

This robotic system dissects the mosquito with the following sequence of events: a mosquito is placed on the turntable, which is then picked up by a gripper to the cutting station. Then, the mosquito is decapitated and is then transferred to the squeezing station, where the mosquito is compressed onto the squeezer to extract a salivary gland. The corpse and head are discarded, and the salivary gland is collected.

This system has many components, stages, and operations that require computer vision for complete autonomy. For example, the mosquito must be detected for the gripper to pick up, and the neck must be identified for the insect to be decapitated. In addition, quality control must be employed in order to keep the system clean and functional. In short, detection, validation, and quality assurance is required for efficient robot workflow and operation.

This project has two main goals:
1) Vision-based control of cutting-blade cleaner
2) Quality assurance for salivary gland collection

To summarize, the first goal will make sure that the cutting blade will be maintained and kept tidy to reduce clutter, traffic, and other computer vision algorithm errors. The second goal is to make sure that the salivary gland exudate collected will be satisfactory based on certain criteria.

Technical Summary
As a general overview, both goals will involve an implementation of both classical and deep learning-based methods. The two approaches will be compared, one will be chosen based on performance and accuracy.

First, the technical approach of the first goal will be explained. The objective is to detect any clutter of any kind around the cutting station and blade. The classical image processing approach will involve a combination of object detection, by thresholding and/or segmentation.

More specifically, if we get the contrast of the image, apply histogram equalization, and threshold the image to detect high pixel values (which would correspond to mosquitos, since mosquitoes are black), this is a simple image processing algorithm to segment the mosquitoes. Then we can count the blobs by labeling connected components.

The deep learning approach would be to acquire many images in order to train a neural network. The NN model could be something like VGGNet or ResNet. More specific details will be explored in time of implementation. I believe that a simple image processing approach would be better suited for this task, since detecting blobs has always been accurate and achievable by classical methods.

Second, the following explains the technical approach of the second goal. The objective is to label “good” exudates from “bad” exudates. This will be from the following criteria:

- Visibility of salivary gland
- Undesirable limbs and organs
- Any other issues such as random debris

The classical image processing approach is not favorable, due to its highly volatile nature of inconsistent features. It can be attempted by applying a region of interest (ROI) and calculating the volume of the exudate with certain geometric assumptions. In addition, we can use foreground-background segmentation to differentiate if there is any undesirable features inside of the exudate.

The deep learning-based approach will be more feasible due to the flexibility and adaptability of a neural network. This will require a huge batch of data and annotations, however. Some communication with Sanaria Inc. will be established in order for the company to assist with the labeling/annotation process.

<u>Deliverables</u>
There are certain deliverables that are expected as a result of the project. For one, a complete system integration of the project to the existing framework. Due to the fact that a deep learning framework exists within the codebase of the robot system, there are guidelines to follow of system integration of whatever task is implemented from the project. This includes ROS integration. Furthermore, it will be beneficial to implement an automated pipeline from images/annotations to training the deep learning model to evaluation/inference. Finally, a report to compare classical methods and deep learning methods is necessary in order to empirically determine which approach to take.

Minimum	Relatively accurate algorithms for both tasks
Minimum	An empirically executed experiment report to compare classical + DL methods
Expected	Complete integration with ROS robot workflow
Expected	A report on the Gitlab repository for documentation and codebase organization
Maximum	Implementation of automated neural network training workflow with no intermediate user input
Maximum	A set of labeled images from Sanaria Inc.

Key dates

Week(s) #	Activity
1	Begin data organization & setup as well as establish contact with Sanaria Inc.
2-4	Classical methods' scripts written
4-6	Deep learning training scripts written
6-8	System integration
8-11	Improvements/Optimization Period
11-12	Final organization and produce validation results
12	Final Presentation

Logistics and Dependences

In addition to the Monday weekly meetings with the entire team and the weekly vision team meetings, any other necessary meetings will take place. There will be constant communication with Dr. Taylor, the PI of the project, as well as Sanaria for image annotations.

A Gitlab repository is used for version control and collaboration, the computer used for neural network training will be in Dr. Taylor's robotorium pod. There is a dependency of Sanaria employees getting back with image annotations. There will be constant communication, but it will be a limiting factor in terms of actual training until they are received.

Reading List

Phalen, Henry, et al. “A Mosquito Pick-and-Place System for PfSPZ-Based Malaria Vaccine Production.” *IEEE Transactions on Automation Science and Engineering*, vol. 18, no. 1, 2021, pp. 299–310., https://doi.org/10.1109/tase.2020.2992131.

Schrum, Mariah, et al. “An Efficient Production Process for Extracting Salivary Glands from Mosquitoes”

Planned	**Done (as of May 1, 2022)**
Relatively accurate algorithms for both tasks	Yes
An empirically executed experiment report to compare classical + DL methods	N/A
Complete integration with ROS robot workflow	Somewhat (pushed to Git)
A report on the Gitlab repository for documentation and codebase organization	In progress
Implementation of automated neural network training workflow with no intermediate user input	In progress*
A set of labeled images from Sanaria Inc.	No

** This was done for the other existing tasks instead*