Working title: Autonomous Artificial Pollination Robot with Deep Learning based Robotic Manipulation

Background: For many commercial crops today, relying on insect pollination is not possible. Approximately $24 billion per year worth of crops depends on natural pollinators like bees [1]. However, declining natural bee populations and an increasing demand for pollinators have resulted in increasingly expensive costs for farmers. While addressing the decline of natural pollinators, more and more farmers have turned to artificial pollination methods, such as hand pollination or robotic pollination systems. In greenhouses, hand pollination and imported bumblebee populations are commonly used to pollinate plants. There have been many autonomous, robot based approaches to this problem as well, but they still face major challenges to efficient and commercial use.

Contribution/Innovation:

1. Hybrid approach with image processing and Deep Learning algorithms optimized for pollination accuracy and power efficiency integrated with real-life robotic manipulation in the context of artificial pollination
2. Design of an innovative and low-cost end-effector
3. Integration of pollination system with autonomous drone-based robot for efficient pollination
4. Two-stage approach for mapping, task/path planning, localization, navigation, object detection, robotic control

Description: Artificial pollination can be broken up into three parts: pollen collection, pollen processing, and pollen deposition. However, the focus of this project is purely on pollen deposition. An autonomous drone-based artificial pollination system is especially suited to use in controlled environments like a greenhouse. With the absence of wind, equally spaced, and tightly packed plants, greenhouses that grow common vegetables that require cross pollination are suitable for robotic pollination systems. Using a drone equipped with a camera to detect flowers and a payload equipped with a robotic sprayer attachment to spray pollen onto flowers, the last stage of artificial pollination, the deposition of the pollen on the stigma, can be accomplished. The drone will be responsible for rough positioning and the payload will put the sprayer head into place with more precision. The control of the sprayer system will be accomplished using a deep learning based approach in order to efficiently and precisely accomplish pollination. A deep learning approach will maximize the efficiency of pollination along with greatly decreasing the time and effort required compared to hand-engineered control algorithms.

The drone will be built from a fully open-source programmable drone kit and modified to fit the tether connected to the payload. Because the tether supplies both power and data connections, the drone frame must be modified to connect to the tether. Onboard the drone, a computer vision system detects markers and flowers. A SLAM algorithm will be used for localization and path planning.

The payload consists of a platform and container connected to a precision sprayer head for depositing the pollen on the stigma of the flower. The payload will need a small camera and two servos to position the sprayer head relative to each flower.

Use case/Scenario: A greenhouse with plants flowering during winter. The drone is placed into the greenhouse and moves between markers, mapping out the locations of flowers. After mapping is completed, it moves between the flowers to pollinate each one.

Objective: The objective of this project is to build an autonomous system that can efficiently pollinate cucumber plants in a closed greenhouse.

https://arxiv.org/abs/2102.04148

Robot control example: https://arxiv.org/abs/1509.02971

Key features:

- Mapping, localization, (in door) navigation, motion planning, and control
- SLAM, Object Detection, Robotic manipulation
- Drone+Payload
- Use single vision camera (RGB camera), not use RGB-D camera, or stereo camera, or LIDAR
- 3D Mapping
- Hybrid: Simulation-based (ROS/Gazebo/MoveIt) + Hardware for the payload (sprayer)

ROS with Drone:

- **Built-in one in ROS: http://wiki.ros.org/hector_quadrotor (has SLAM, it's not autonomous)**
- **https://github.com/wilselby/ROS_quadrotor_simulator**
- **https://github.com/NishanthARao/ROS-Quadcopter-Simulation**
- **https://link.springer.com/chapter/10.1007/978-3-642-34327-8_36**
- **https://drone.sjtu.edu.cn/contest/wp-content/uploads/2013/11/ROS_Gazebo_Quadrotor_simulator.pdf**

Payload:

- **Pan-tilt-(zoom) camera with sprayer (mechnism)**
    - **http://wiki.ros.org/pan_tilt_robotis**

SLAM with DL

- **Survey: https://arxiv.org/pdf/2006.12567.pdf**
- **https://www.researchgate.net/profile/Ilya-Afanasyev-3/publication/311085504_Comparative_analysis_of_ROS-based_Monocular_SLAM_methods_for_indoor_navigation/links/59d6a0610f7e9b42a6aa0547/Comparative-analysis-of-ROS-based-Monocular-SLAM-methods-for-indoor-navigation.pdf**
- **http://www.artificialhumancompanions.com/slam-autonomous-navigation-deep-learning-robot/**