Precision Pollination Robot

PI: Yu Gu, Co-PIs: Jason Gross, Xin Li, Yong-Lak Park,
Nicole Waterland, West Virginia University

Robotic Precision Pollination

Motivation:

- Pollinators contribute $24B/year to the U.S. economy
- The decline of native pollinators has threatened food productivity
- The ability to precisely localize, evaluate, and manipulate small and delicate plant parts is fundamental to precision agriculture

Photo: the Independent

Long-Term Vision:

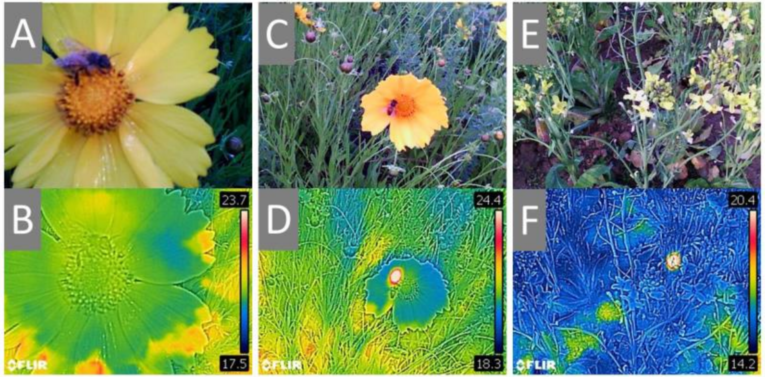
- Enable precision robotic services to a variety of crops in both field and greenhouse environments

Project Objective:

- Design a pollinator robot and perform proof-of-concept demonstrations of its effectiveness for bramble (i.e., blackberry and raspberry) pollination in a greenhouse environment

Bee Studies

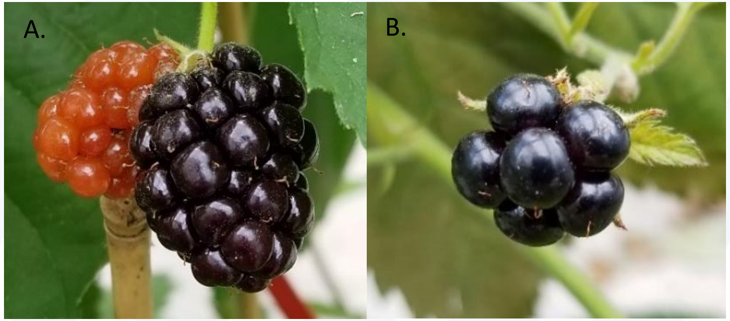
- Investigating the structure, function, and behavior of bees while interacting with flowers to gain bio-inspirations for robot design



O. conjuncta *O. atriventris* *O. georgica*

Bramble Flowers

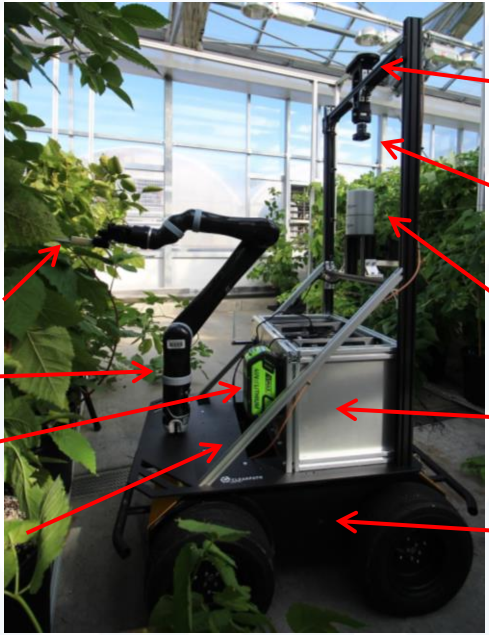
- Bramble cultivars suitable for robotic pollination experiments were selected and grown
- The process of flower development was recorded and analyzed
- The structure of flowers was examined for supporting robot end-effector design
- A 5-row trellis system with netting was constructed in the greenhouse



Pollination affects fruit quality. Average blackberry fruit (A) Blackberry fruit resulting from poor pollination (B).

BrambleBee: the Pollination Robot

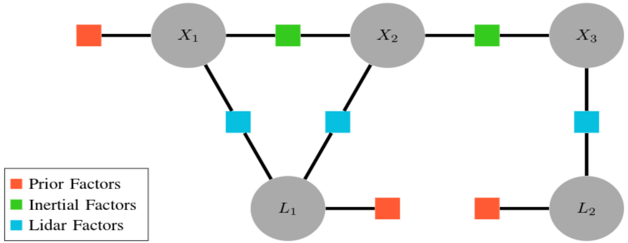
- BrambleBee is equipped with state-of-the-art navigation sensors, manipulator, computing resource, and a custom designed pollination end-effector

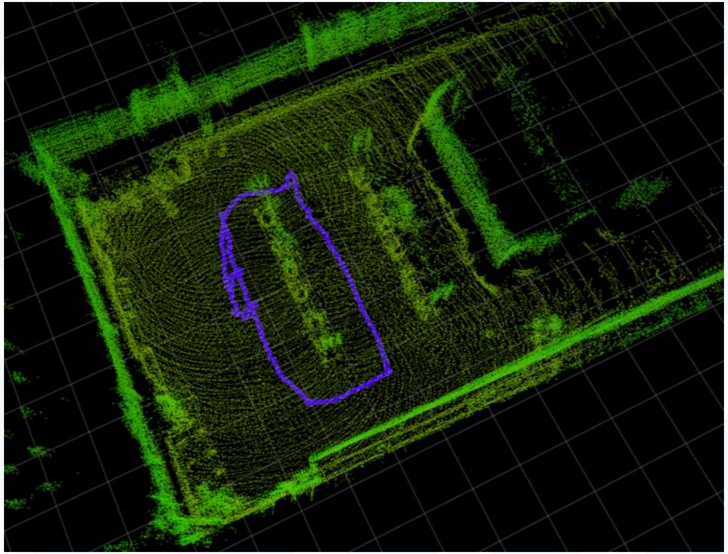


Localization and Mapping

SLAM Using Lidar, Inertial, and Odometer Measurements

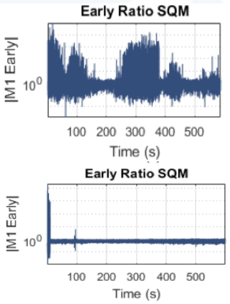
- Generalized ICP for scan matching (front-end)
- Factor graph (back-end) for optimization
- Loop closure:
  - Matching a prior map to the current Lidar scan
  - Providing a transformation between the SLAM map and the prior map

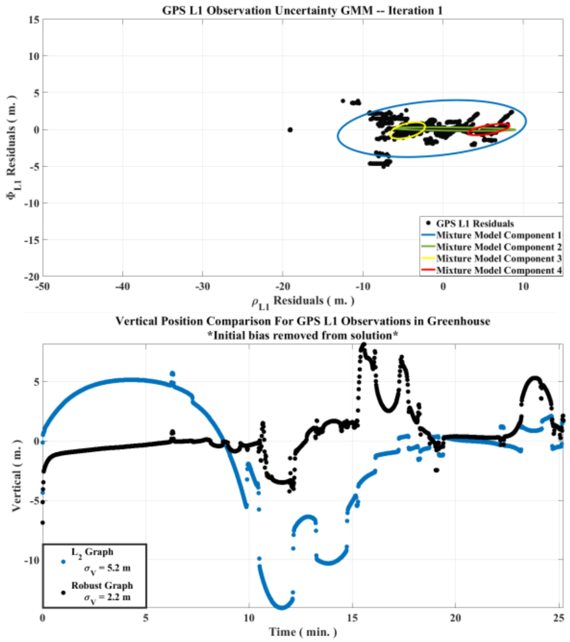




Degraded GNSS Data Processing

- Due to signal reflectance, accurate GNSS processing is difficult inside of a greenhouse
- We collected raw GNSS data with a software defined receiver and have been investigating:
  - using real-time receiver signal quality metrics
  - applying a clustering based uncertainty quantification technique for robust optimization

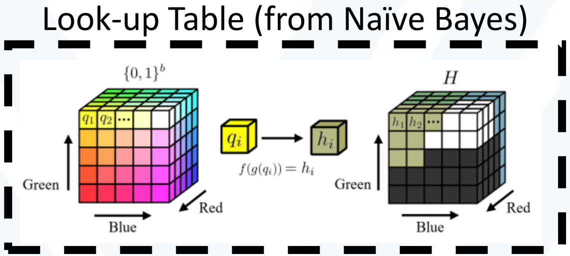


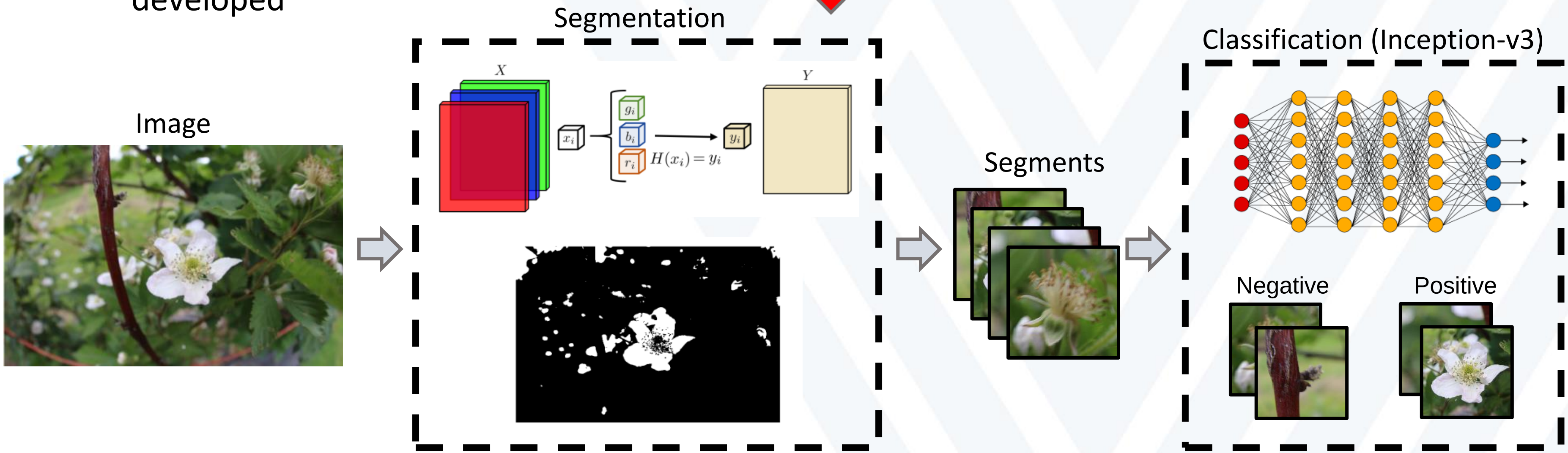


Example robust optimization estimates. Iterative clustering (top). Vertical positioning (bottom)

Flower Detection Pipeline

- A large set of flower data was collected to train the image classifier
- Fast image segmentation method was developed





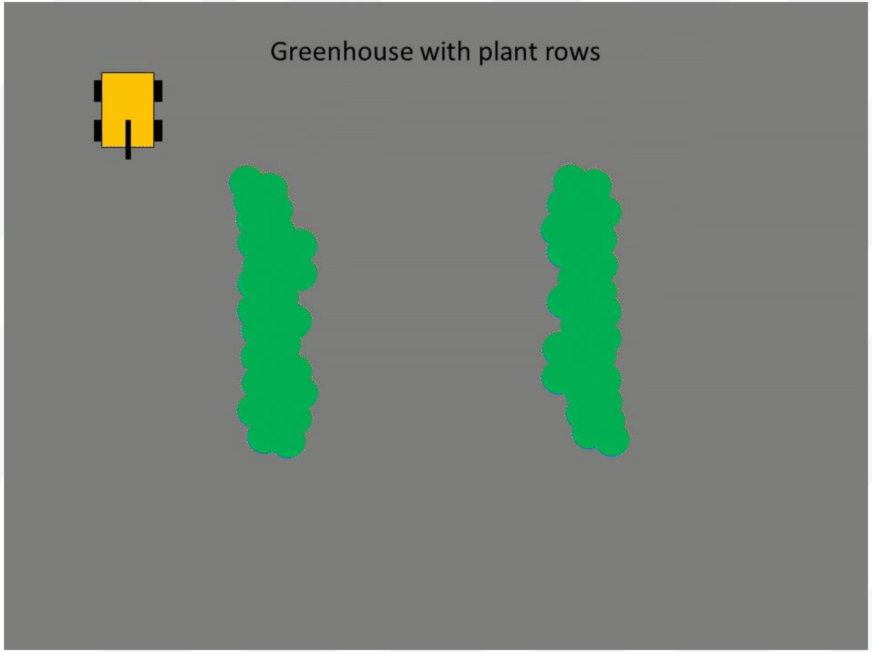
Autonomy and Planning

Greenhouse Survey Pass:

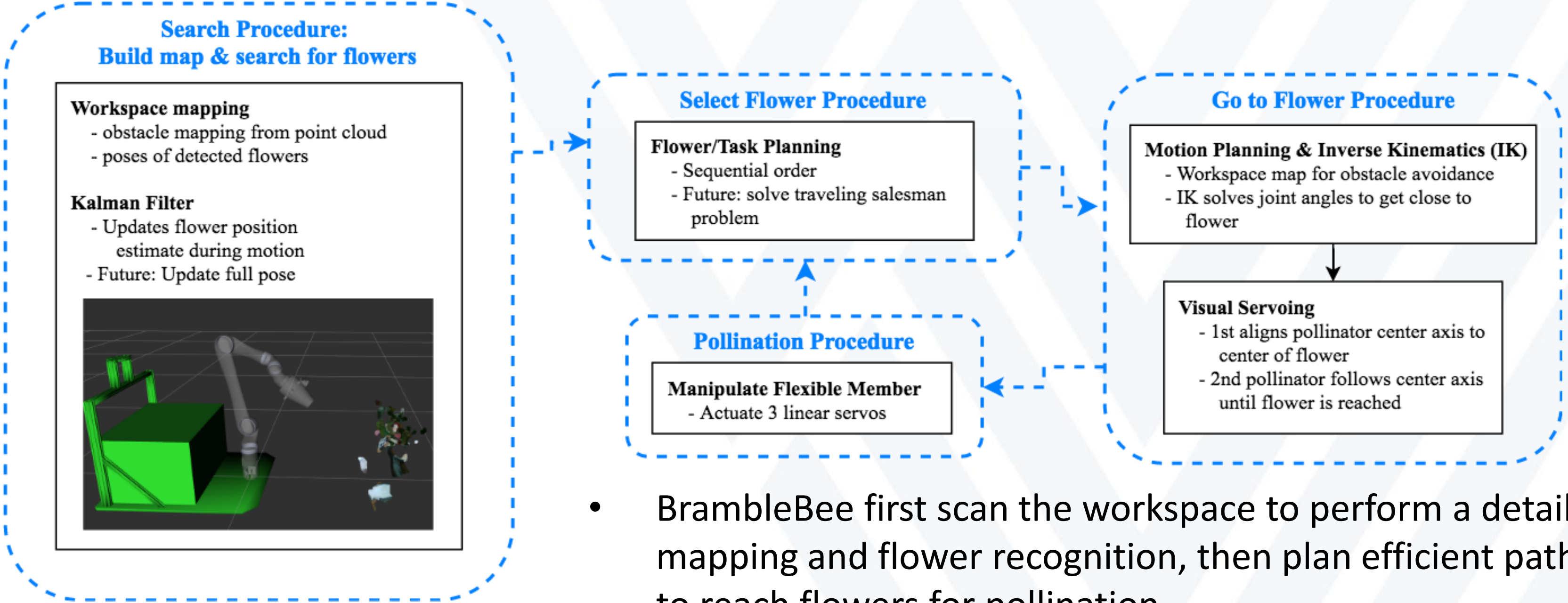
- Map the environment
- Identify flower cluster locations
- Estimate pollination readiness

Pollination Pass:

- Choose robot parking locations
- Maximize reachable flowers
- Minimize distance driven
- Weight importance of flowers (e.g., the ones near the end of pollination viability are weight higher)
- Plan pollination sequence



Flower Manipulation



- BrambleBee first scan the workspace to perform a detailed mapping and flower recognition, then plan efficient paths to reach flowers for pollination

BrambleBee in Action

Video:
https://www.youtube.com/watch?v=66isrgth7-Q

Publication and Media Coverage

Publications:

- Ohi, N., Lassak, K., Watson, R., Strader, J., Du, Y., Yang, C., Hedrick, G., Nguyen, J., Harper, S., Reynolds, D., Kilic, C., Hikes, J., Mills, S., Castle, C., Buzzo, B., Waterland, N., Gross, J., Park, Y., Li, X., Gu, Y., "Design of an Autonomous Precision Pollination Robot," IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Madrid, Spain, October, 2018.
- Park, Y.-L. Osmia cornifrons as a model for pollinator robot. The Apicultural Society of Korea Annual Conference. Gwangju, Korea, 2018.
- Park, Y.-L. Pollinator robot inspired by structure and behavior of Osmia bees (Hymenoptera: Megachilidae). Annual Meeting of Entomological Society of America, Denver, CO, 2017.
- Park, Y.-L. Precision pollinator robot. Annual Meeting of West Virginia Entomological Society, Cairo, WV, 2017.
- Park, Y.-L. Bees: current issues, future prediction, and mitigation. Annual West Virginia Extension and Master Gardeners Conference, Roanoke, WV, 2017.
- Park, Y.-L. Mason bees: propagation and management. West Virginia Panhandle Beekeepers Association Meeting, Martinsburg, WV, 2017.

Media:

National Geographic Italia
TechXplore
Digital Trends
Wired
American Fruit Grower
IEEE Spectrum
Fast Company
Vegetable Growers News
Now Future
Fruit Growers News

Plan for the Next Year

1. Integrate robot system with the ability to complete the entire pollination sequence autonomously:

- Perform reliably detection and pose estimation of individual flowers in dense flower clusters
- Optimize planning algorithms for both the drive base and the manipulator
- Refine and finalize the pollination end-effector design
- Extend autonomy capabilities to make flexible pollination decisions
- Refine the final sequence of pollination actions on real flowers

2. Evaluate the efficacy and efficiency of multiple pollination methods.

- Compare five methods of pollination: bee pollination, manual pollination, autonomous robot pollination, and mixed human-robot teaming on pollination

Poster 27