Robot-assisted Field-based High Throughput Plant Phenotyping

[1]Changying Charlie Li, [1]Javad Mohammadpour, [2]Andrew Paterson
[1]Rui Xu, [1]Yu Jiang, [1]Shangpeng Sun, [1]Liujun Li, [1]Piyush Pandey, [1]Rikki Brown, [1]Saba Faryadi, [1]Mohammadreza Davoodi
[1]College of Engineering
[2]College of Agricultural and Environmental Sciences
University of Georgia, Athens, GA, 30602

Background and goals

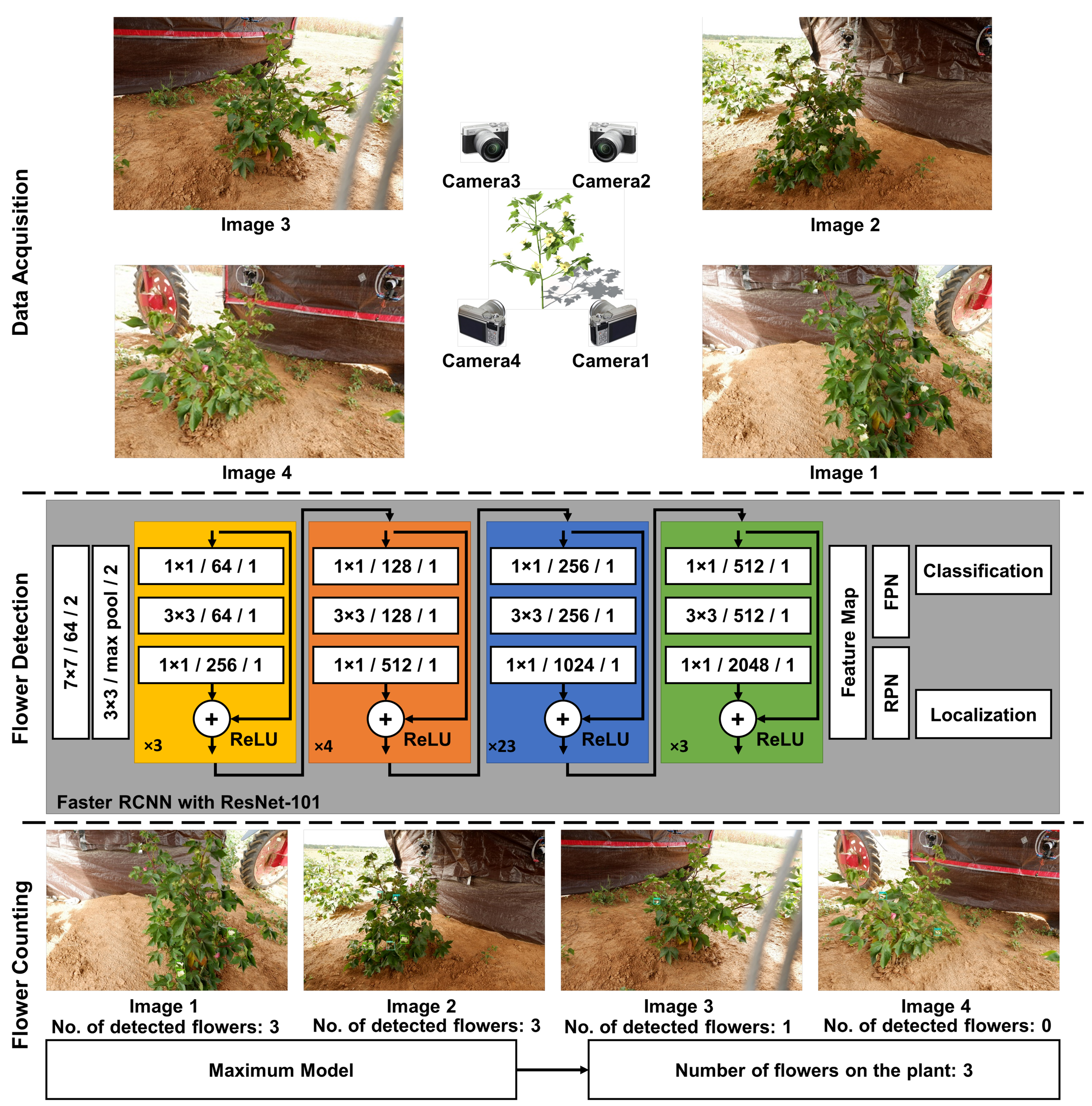
Background: The global population is projected to exceed nine billion by mid-century. To meet the demand of food, feed, fiber, and fuel, agricultural production must double. Further, global climate change will make it harder to grow agricultural crops in many parts of the world. The genomics revolution provides unprecedented power to engineer new and advanced crop cultivars with the gene combinations needed to support the rapidly increasing world population while adapting to the changing climate. Currently, relating molecular signatures to key differences in phenotype (such as plant or root architecture, yield, and stress or pest resistance) has been laborious, expensive, and imprecise, requiring manual assessment of one plant at a time for traits that may be difficult to score visually. As such, rapid and repeatable measurement of crop phenotypic parameters is a major bottleneck in plant breeding programs.

Our long term goal is to develop robot-assisted high-throughput phenotyping technologies that can quickly scan thousands of individuals using an array of advanced sensor and data analytic tools which are crucial for improving our ability to dissect the genetics of quantitative traits such as yield and stress tolerance. Specific objectives are to: 1) develop ground and aerial robotic systems and data analytics for phenotypic traits measurement; 2) Investigate coverage control algorithms for heterogeneous robots to work cooperatively; 3) design convolutional neural networks for phenotypic traits extraction; 4) validate the robotic systems in the field for QTL studies.

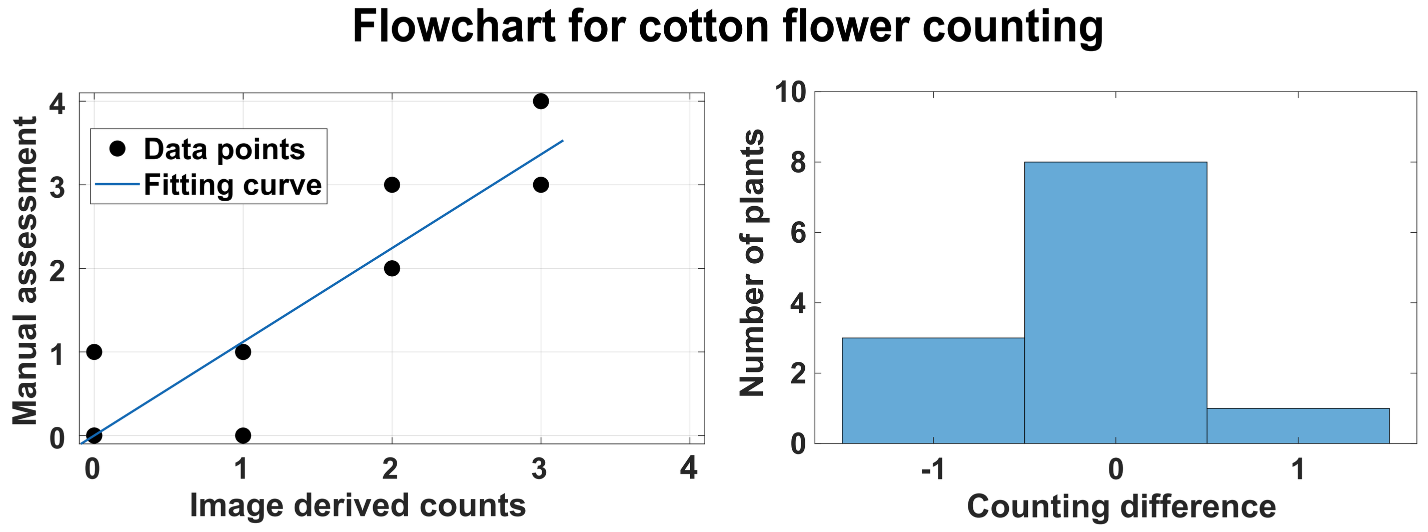
Research Progress in 2018 (Second Year)

Deep Learning for Flower Count

To more accurately count cotton flowers, we used a ground phenotyping system and four color cameras to take ground images for cotton plants. We trained a faster RCNN with ResNet-101 using TensorFlow to detect flowers in the image. The detected number of flowers is consistent with manual count with a reasonable accuracy.



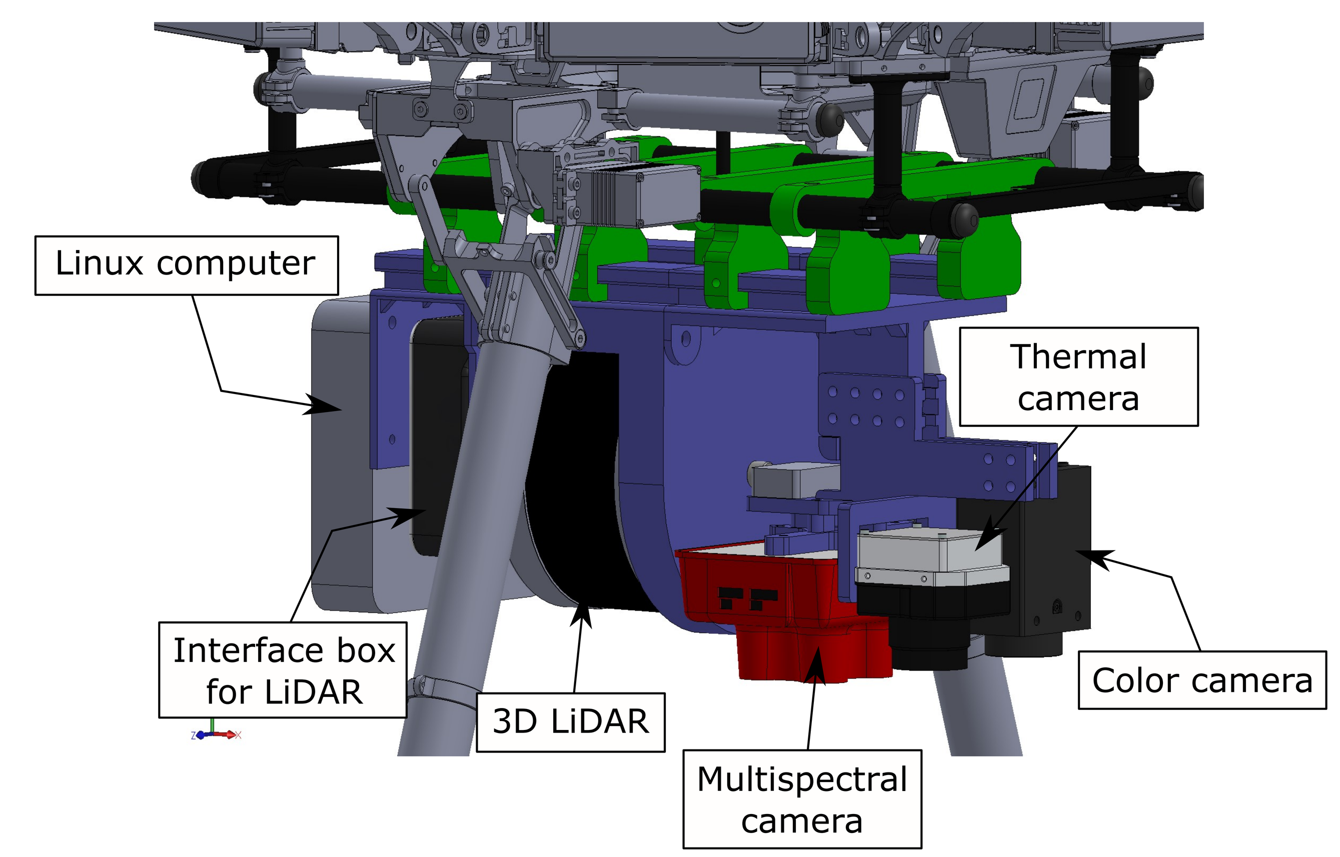
Flowchart for cotton flower counting



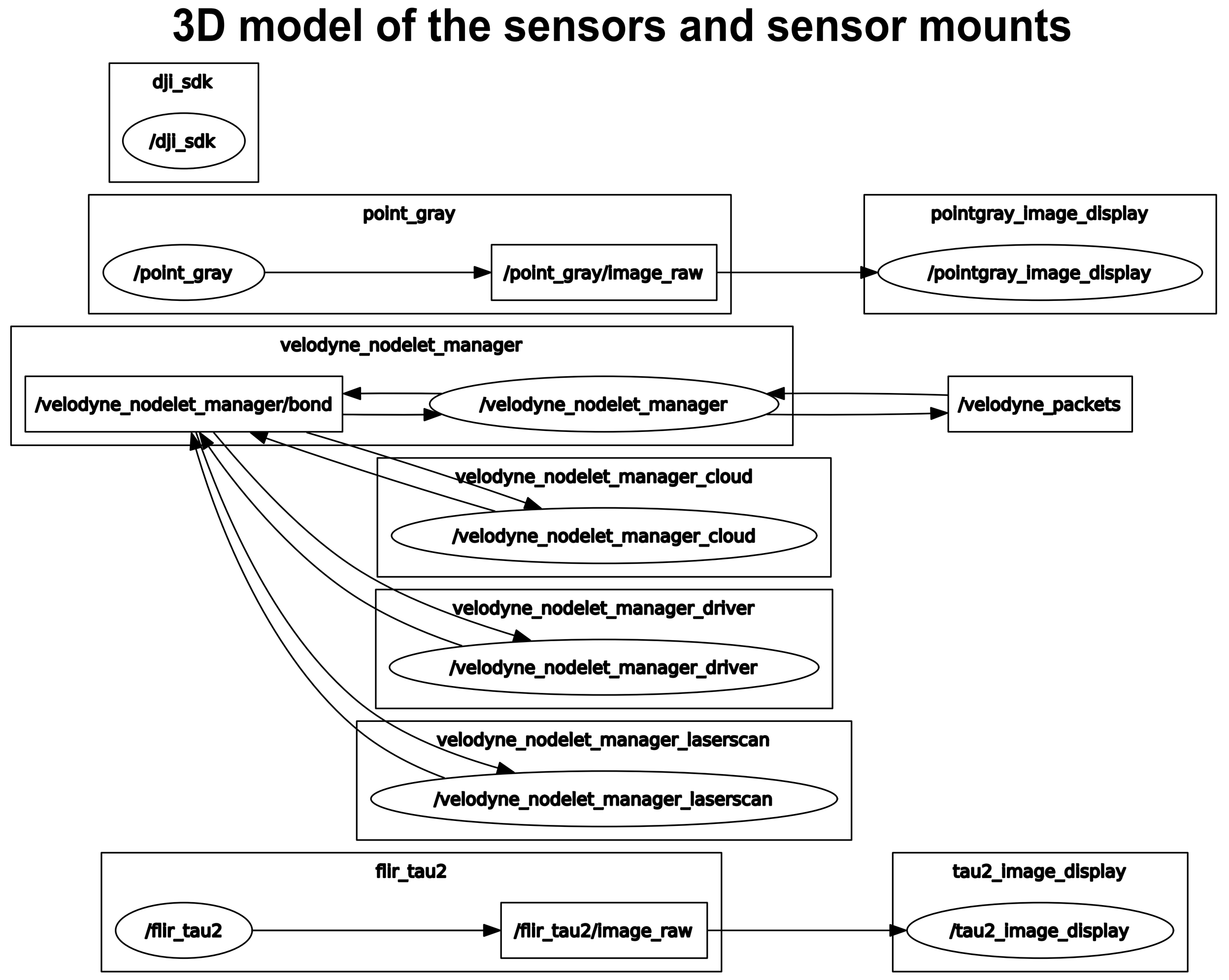
Results of the cotton flower counting

Unmanned Aerial System

We developed an unmanned aerial system for data collection. We designed the mounting brackets for the sensors in CAD software and printed them in ABS using a 3D printer. In this way, the design can be used by other researchers. A miniature Linux computer was used to control and acquire data from the sensors. The data acquisition program was implemented using Robot Operating System (ROS), so it can easily add new sensors and communicate with ground robots.



3D model of the sensors and sensor mounts



ROS computation graph of the data acquisition program

Coordinated Control of UGVs

In the second year of the project, we first developed a new coverage control algorithm for a group of autonomous ground robots and validated it in a lab-scale test bed. To this aim, the field, whose map had been constructed using drone images, was first modeled by a weighted directed graph. Important areas on the field were detected and identified on the graph using a distributed density function. Next, this information was sent to the developed distributed energy-aware deployment algorithm, and the robots were then optimally deployed in such a way that coverage of the whole field and monitoring of the areas of interest were maximized. In addition, a tracking control algorithm (at the robots' level) based on the state dependent Riccati equation (SDRE) technique was developed to avoid collision of robots with plants and with each other by keeping them to move on straight lines (edges) between nodes. Figure below shows the general block diagram of the proposed two-level control.

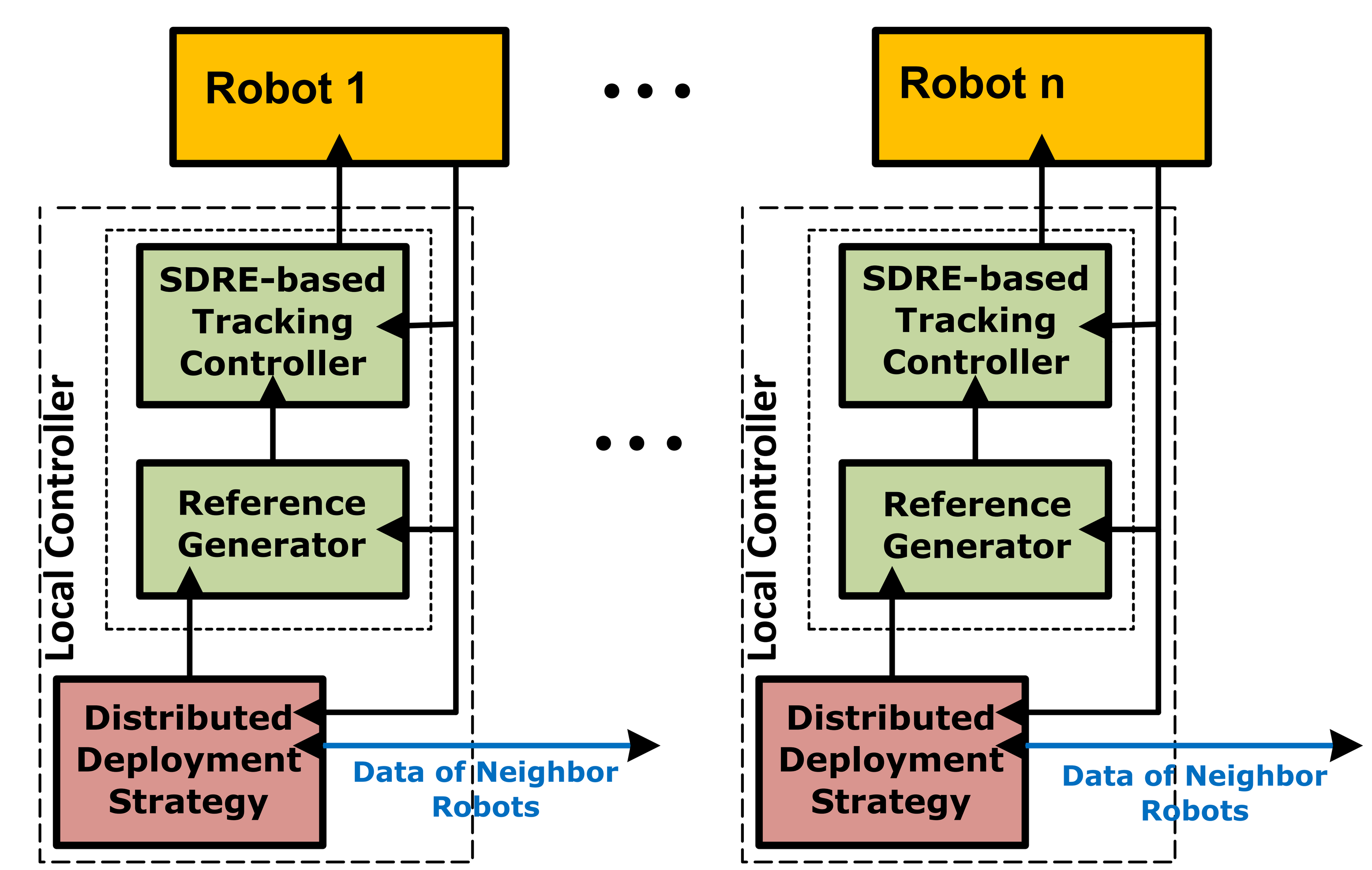


Diagram of the robot control

Acknowledgement

United States Department of Agriculture
National Institute of Food and Agriculture

This project is supported by the NSF and NIFA National Robotics Initiative Program.