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United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1031064

Project Title

A smart ground-based vision system for automated inventory management and quality evaluation of ornamental nursery crops

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** COMPLETE
Funding Source NIFA Non Formula	**Grant Year** 2023
Grant No. 2023-67021-40617	**Cumulative Award Amt.** $299,961.00
Proposal No. 2022-11126	**Multistate No.** (N/A)
Project Start Date Jul 15, 2023	**Project End Date** Jul 14, 2026
Program Code [A1521] Agricultural Engineering	

Project Director

Rehman, T.

Recipient Organization

AUBURN UNIVERSITY

321-A INGRAM HALL

AUBURN, ALABAMA 36849

Performing Department

(N/A)

Non Technical Summary

Accurate inventory management and quality assessment are critical tasks for monitoring sales, yield, space requirements, production timing, and quality improvements of ornamental nurseries. The current standard for inventories and quality assessments is counting thousands of plants manually. The process is inefficient, time-consuming, labor-intensive, likely inaccurate, and expensive. Since the U.S. farm labor pool is consistently decreasing and is expected to shrink long-term, an automated inventory management system is needed to meet the national and global goals for sustainable practices. The main objective of this project is to develop and test a smart ground-based vision system for automated inventory management and quality evaluation (e.g., canopy architecture, color, uniformity, and homogeneity) of ornamental nursery crops. Actively illuminated multispectral imaging with occlusion-aware deep convolutional neural networks will be used for plant segmentation and quality assessments. The system performance

will be evaluated incommercial nurseries at different growth stages and levels of canopy occlusion. The secondary objective is to use image-based quality parameters to re additional information to nursery managers about the spatial and temporal distributions of plant health across different nursery beds, seasons, and years. Stakeholders can use this knowledge to fine-tune the management practices and mitigate unforeseen production risks.The proposed automated inventory management and quality assessment system will provide near-term and long-term solutions for nursery managers to improve ornamental nursery production efficiency, profitability, and sustainability.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	20%
Applied	50%
Developmental	30%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
402	2110	2020	100%

Knowledge Area

[402] Engineering Systems and Equipment

Subject Of Investigation

[2110] Ornamental trees and shrubs

Field Of Science

[2020] Engineering

Keywords

automation, machine learning, multispectral imaging, Ornamental inventory management

Goals / Objectives

The overall goal of this project is to automate inventory management and quality assessment tasks for the U.S. ornamental nursery industry. By and large, the current standard for inventories is manually counting thousands of plants.Inventories for 1 and 3-gallon nurseries can range from 30,000 to 80,000 plants per acre. To automate the inventory management system and to tackle the associated data science challenges, in this project, we plan to pursue the following three specific objectives: 1)Develop an unmanned ground vehicle (UGV) equipped with a multispectral imaging system to collect video data from commercial ornamental nurseries,2)Develop a comprehensive deep learning-based multispectral video processing pipeline capable of segmenting, tracking, and evaluating the quality

status of individual nursery plant instances, and 3)Evaluate the performance of developed UGV and video processing pipeline for inventory management and quality assessment in commercial nurseries at different growth stages and levels of occlusion.

Project Methods

Objective 1: A ground robotic multispectral imaging platform will be developed to automate inventory management and quality evaluation of ornamental nursery crops. A custom electric unmanned ground vehicle (UGV) will be built as an imaging platform with an integrated suite of sensors, including an RTK-GNSS module, an IMU unit, wheel encoders, and pair of multispectral cameras. The imaging system will consist of two multispectral cameras and lighting modules to acquire reflectance images in 405 nm, 560 nm, 660 nm, and 880 nm bands. These bands are selected as the reflectance in visible and near-infrared (NIR) contains significant information on plant health. An industrial-grade, monochromatic camera will serve as a sensor. The lighting module will consist of a light-emitting diode (LED) board containing blue (405nm), green (560nm), red (660nm), and near-infrared (880nm) LEDs arranged uniformly across the lighting board. A Teflon plate will be used to diffuse lights and avoid hotspots properly. Each multispectral camera will be stabilized using a 3-axis gimbal and connected to an edge computer for control, monitoring, and data storage. Objective 2: Spatial counting and mapping of the ornamental plants in the videos will be investigated using state-of-the-art deep convolutional neural networks (CNNs). The multispectral video streams will be pre-processed using normalized difference vegetation index (NDVI) to segment the background. For early-stage plants, simultaneous instance segmentation and tracking of the unique plants will be performed. The occlusion-aware instance segmentation networks or temporal feature calibration modules to complement MaskTrackR-CNN will be tested for the late-stage plants with occlusions. To assess the quality of each plant registered in the inventory, we will develop a scoring mechanism based on canopy color, shape, and texture. To quantify the color, we will use RGB and NIR-based indices. The shape and spread of the top-view canopy will be quantified by computing the morphological features. The homogeneity and uniformity of the canopy will be extracted from the color co-occurrence matrices. To reduce annotation and accelerate dataset curation, active learning and interactive image annotation tools such as Computer Vision Annotation Tool will be employed.Objective 3: To test the proposed system, two commercial nurseries will be used to conduct field experiments. Three of the most popular crops from these nurseries will be used for evaluating the proposed system. At an early-stage nursery visit, the boundaries of each bed will be mapped with the help of RTK-GNSS. Plants will be manually counted for each bed, and the quality of each plant will be visually scored by the nursery personnel that usually collect inventory data. The time required to access the quality and count the plants will be recorded. After data collection, five parameters, including total count error, count accuracy, false positives (multiple counts), false negatives (missed a count), and time efficiency, will be used for evaluation. To test the system performance at different occlusion levels, two nursery beds with two different levels of container spacing (a total of four beds) will be created for each plant. These treatments include canopy edges touching together (4-6 inches of container spacing) and canopy edges occluding each other (2- 3 inches of container spacing).