Autonomous navigation in cotton fields using deep learning

C. Mwitta¹, G. Rains², E. Prostko³
¹College of Engineering, ²Department of Entomology, ³Department of Crop and Soil Sciences, University of Georgia

Introduction

- Importance of autonomous navigation in agriculture:
  - Improves precision agriculture practices (targeted weeding, spraying, harvesting, etc.)
  - Reduces costs and need for human labor
  - Enhance operation safety and improve productivity

- Challenges:
  - Uncertainties of outside environment (weather changes)
  - Inconsistent illumination, shadows
  - Obstacles, occlusion
  - Weeds, crop growth stages, row spacing

- Possible solutions for autonomous navigation:
  - GPS navigation – mostly used (Cons: Availability issues due to atmospheric conditions, inability to detect obstacles)
  - Computer vision technologies – e.g., using RGB cameras for color segmentation (Cons: sensitive to weeds, illumination), LIDAR (Cons: expensive)
  - Deep learning – discriminating between rows and paths, e.g., Convolutional neural networks, Semantic segmentation using neural networks

- Selected solution for this study:
  - Fully convolutional neural network (FCN) for semantic segmentation model (famously ‘U-Net’), was chosen due to its robustness against changes in illumination, weeds presence, shadows, occlusion, and crop growth stages
  - The model detects path between crop rows which is then used by the vehicle to autonomously navigate

Methods

- Data collection: Cotton rows and paths (80%), validation set (10%), Testing set (10%)
- Model training:
  - More than 400 labelled image to indicate the path between cotton rows
  - Training dataset (80%), validation set (10%), Testing set (10%)

Rover navigation

- Rover navigation
  - Two (2) periods of growth stages (early and late)
  - Rover navigating at 1mph
  - Eight (8) 30-feet plots per stage
  - Position data recorded in 1-feet intervals
  - Three (3) different camera angles

Results

- Semantic segmentation model
  - Robust against different lighting conditions, shadows, cotton growth stages, weeds
  - Two-sample t-test showed no significant difference between the rover physical position and the predicted position
  - There was no significant difference between the seasons position deviations

Conclusions and Discussion

- Conclusions
  - Fully convolutional neural network for semantic segmentation model proved to be an effective method of detecting paths between crop rows
  - The model was robust against illumination, shadows, row discontinuities, camera angle, and cotton growth stages
  - Mapping from image domain to ground plane was effective in determining the position of the rover which enabled it to navigate successfully
  - Minor inconsistencies were observed on paths which were extremely occluded by cotton leaves in late growth stages

- Discussion
  - More training examples will improve detection especially in late stages of growth
  - Sensor fusion techniques can improve row following task (e.g., GPS fused with machine vision)
  - The camera can also be used to avoid obstacles and ditches