Transitioning to Robotics in Row-Crop Production

Santosh K. Pitla, PhD
Associate Professor
Advanced Machinery Systems Laboratory (AMSL)
Department of Biological Systems Engineering
University of Nebraska-Lincoln
Overview of the Presentation

• Trends in Ag-Robotics in Row-Crop Systems
• Considerations For Transitioning to Robotics in Row-Crops
• Nebraska Robotic Test-Beds & AI
• Q&A
More water please!!

More fertilizer please!!

Less pesticides please!!

By the way, I hate those weeds can you take care of them?

“Carl” the Corn Plant

Weeds

Ag IoT
You will get a Call, text, tweet, or an email message from Carl the Corn Plant
30,000 Plants/acre

6 million Plants for a 200 acre field

Matrix of plants with multi-dimensional data vectors
Ag-Robot taking care of Carl
Going from “per acre management” to “per plant or per sq.ft management”

Per Plant Crop Management using Ag-Robot Swarms: Optimum management of water, chemicals, and fertilizers to minimize impact on the Environment while Increasing Yields

Water and Chemical Savings

Inter-Cropping System for Soil health improvement and profitability

Targeted weed management

Reduce wastage of fertilizers
Current Machinery Trends- High Horse Power Tractors

**Case IH Steiger 620 Quadtrac**

- Engine: FPT 12.9L 6-cyl diesel, 620 HP
- Ballasted Weight: 60,000 lb
- Life: 20,000 h

Source: Nebraska Tractor Test Laboratory
Balzer 2000
Capacity – 2,000 bu
Total Loaded Weight – 76.4 ton
Unloading Time – 120 s

Current Machinery Trends - Grain Carts

The effect of Tractor Mass on crop yield (Johnson 2009)
Current Machinery Trends - Planters

Xerion 5000 tractor with a 48-Row Planter (120 ft wide)
Source: CLAAS-Omaha
Current Machinery Trends- Sprayers

Spray material Application Variation (Luck and Pitla, 2010)
Robots in Row-Crop Production

Auto Cart (Smart Ag – Raven Autonomy)

DOT Platform (Raven Autonomy)
Robots in Row-Crop Production

A Multirotor UAS collecting multispectral images of soybean plots
(Photo Credit: Michael Sama, University of Kentucky)

Spraying Drones (Rantizo)
(Source: https://www.commercialuavnews.com)
Trends in Machine Automation and Robotics
Row-Crop Production

Next-Generation Machinery Systems (2040)
Robotic Swarms – Nebraska Test-beds
Ag-Robot Swarms in Row Crop Production

Farming-as-a-Service (FaaS), SabantoAg
(Source: https://www.dtnpf.com/)

Use of Multiple Ground Robots, Swarm Farm
(Source: https://www.farmonline.com.au/)
Ag-Robot Swarms – Field Scale Neutral Solutions

Case IH 620 Quadtrac Diesel
600 HP

48-Row Planter

10 Ag-Robots @ 60 HP
Transition Considerations in Row-Crops

Case IH 620 Quadtrac Diesel

48-Row Planter

DOT Platform with Seed Master (Source: Raven Autonomy)

Sabanto Ag– FaaS (Source: DTN The Progressive Farmer)

Earth Sense and TerraSentia (Source: https://news.valley.farm)
Considerations For Transitioning to Robotics in Row-Crops

- Current Equipment Set (Partial or Full replacement with Robots?)
- Initial Robotic Field Operations
- Implement interface with Autonomous Devices
- Logistics of Material Refilling
- Multi-Purpose Robots
- Level of Autonomy and Interaction with Manned Machinery
- Field connectivity and inter-robot communication
- Electrification and Autonomy
Coordination Strategies among Multi-Robot Systems

MRS planting in unique work zones (WZ I to WZ III)

Multi-Robot System Control Architectures (POSSELIUS & Pitla et al., 2016)
Nebraska Robotic Test Beds: inter-row robot (i-RASP)

Nebraska Robotic Test Beds: Flexible Structured Robotic Vehicle (Flex-Ro)

- 57 hp hydrostatic drive machine
- Independent electrically driven steering
- Adjustable track width
- Foot print (10 ft X 10 ft), Clearance: 4 ft
- 16-gallon gasoline tank
  - 14-hour run-time
Multi-Purpose Nature of Flex-Ro Robot

- Not suitable for sensing or phenotyping
- Liability

Vs

- Modular Structure
- Multi-Purpose Platform
- Reduced Liability
Nebraska Robotic Test Beds: Flexible Structured Robotic Vehicle (Flex-Ro) – Four Wheel Steer

Flex-Ro on NTTL Test Track
Nebraska Robotic Test Beds: Flex-Ro

Control System Hardware
• CAN bus network
• 10 ECU nodes
  • 9 – low level controllers
  • 1 – main controller
  • Remote
  • Supervised Autonomy
Obstacle Detection

- Ifm O3M 151 3D Smart Sensor
- Time of Flight 64-pixel infrared matrix
- Sends CAN message with obstacle information
Basic Obstacle Detection Test in Controlled Settings

Obstacle Detection
- Implemented automatic reaction
- Stop at 2 m from obstacle
  - 40 cm x 100 cm
- 2 – 10 kph stopped 1.5 – 2 m from obstacle
Flex-Ro’s Phenobar for Field Phenotyping

- RGB Camera
- Thermal Infrared Radiometer
- Ultrasonic Sensor
- Fiber Optics coupled to portable spectrometer
- Electronics enclosure
Flex-Ro Testing in Soybean Field Plots (UNL’s Spidercam Phenotyping Facility)
Phenotyping Data (Soybean Field Plots)
Flex-Ro Canopy Coverage
• Green pixel fraction
• Automatic segmentation
• Limited functionality after full canopy
Nebraska Robotic Test Beds: Green House Robotic Arm

Leaf Grasping Robot for Phenotyping Applications (Atefi et al., 2019)

• **You-Only-Look-Once (YOLO) network**
  • Fully Convolution Neural Network
  • Bounding Box Prediction
  • To detect middle to small static and dynamic objects

• **Semantic segmentation**
  • Fully Convolution Neural Network
  • Pixelwise Classification
  • To detect large static objects and environmental features

Redmon et al., 2016
Badrinarayanan et al., 2017
AI for Field Object Identification – YOLOv2

Freyhof and Liew (2020)
Multiple UASs above the field

Multiple UGVs working in the Field

Cloud

Internet

Edge Computing

Field computer

Animal Barn

Robotic Manipulators

Pitla et al., 2020

Connected Autonomous Systems and Robotics for Crop and Animal Production

Pitla et al., 2020
Thanks for your Time

Q & A and Discussion?

Santosh K. Pitla, PhD
Associate Professor
Advanced Machinery Systems Laboratory
Department of Biological Systems Engineering
University of Nebraska Lincoln

spitla2@unl.edu

https://engineering.unl.edu/bse/faculty/santosh-pitla/