Robotics & AI for Sustainable & Equitable Agricultural Systems

USDA 100th Annual Agricultural Outlook Forum
Panelists

- John Shutske, University of Wisconsin-Madison (moderator)
- Madhu Khanna, Professor and Distinguished Professor in Environmental Economics, University of Illinois
- Ethan Rublee, Founder & CEO farm-ng
- Danielle Boyer, Indigenous (Ojibwe) Robotics Inventor and Youth Advocate – unable to join today
Introduction – Examples of Agricultural Robotics and Other Forms of Automation

• By application
  • Plant production
  • Animal production
  • Environmental applications (monitoring, product application)

• By size and scale
  • Full-size autonomous or highly automated
  • Mid-small size
  • Robots working in fleets or “swarms”

  • Robots for integrated systems and uses (cover cropping, scouting, other)
  • UAV (“drone”) applications

Helper Robots
Animal Care (feeding, milking)
Traditional OEM Field Application
Field/Orchard Application
Driving Forces

• Labor supply

• Desirability of traditional work in agriculture
  • 3D’s – agricultural work traditionally viewed as “dull, dirty, and dangerous”

• Economics

• Leveraging data – enabled by increasingly accessible tools (AI, ML, etc.) for:
  • Natural resource use and protection
  • Worker and public safety
  • Maximizing resource efficiency
Transition from Horses to Mechanization

• Number of tractors > horses in 1954 (U.S.)
• This transition began in the late 1800s
• Seemingly glacial – steam engines, internal combustion, steel wheels, rubber tires
• Lots of pushback, many naysayers
• “Big” revolutions (mid 1900s) – PTO, hydraulics, safety devices, comfort cabs

We Are Now in a Similar Transition Time

- Simple monitors (70s and 80s)
- GPS – yield, mapping, precision application (1990s)
- Auto steer & other features
- Self-diagnostics, text alerts, direct machine-to-service communications
- Machine-to-machine communication
- Autonomy, robotics
My Research Focus: Safety & Risk Assessment

- Agriculture = Most dangerous U.S. industry
- Opportunity to improve safety (remove human from hazard)
- Technology for environmental sustainability
- But – Uncertainty on other risk (bystanders, public, service/repair, risk of downtime, possible environmental risk)
- Risk “unknowns” impacting industry through regulation
- Develop new methods that can “foresee risk” (modeling, learning from past, AI and ML, developing exposure databases)

Thanks to USDA-NIFA and the UW-Madison Agricultural Experiment Station
Contact Information

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Robotics and AI for Sustainable, Equitable Agricultural Systems

Madhu Khanna
Alvin H. Baum Family Chair and Director, Institute for Sustainability, Energy and Environment
ACES Distinguished Professor of Environmental Economics
University of Illinois
Grand Challenges for Agriculture

- Increasing crop productivity while reducing environmental harm
- Substantial heterogeneity in growing conditions within and across fields
- Need for data analytics to enable decision making using “big data” generated by precision technologies
- Shortage of labor
  - autonomous systems that can implement complex decisions with precision and timeliness.
- Crop health monitoring, disease detection
  - Growing resistance to pesticides
Future of Farming: Artificial Intelligence

- Three key features:
- Gather high resolution data on plant and growing conditions
- Autonomy and robotics to make site specific interventions on the field during the growing season
- Machine learning to improve predictive power for making recommendations that can progressively get more accurate over time by learning from the data and experimentation
Robotic Weed Management

• Conventional herbicides applied before plant canopy closes in early stage of growing season
• Small robots can drive under plant canopy, detect and mechanically remove weeds
• Robots have
  • High weeding efficiency
  • Can work long hours
  • Reduce need for labor; depending on level of autonomy
  • Small size: do not cause soil compaction
  • Reduce need for tillage and increase soil organic matter
  • Delay/avoid weed resistance
Cover Crop Planting Robots

- Under the canopy robots can plant cover crop early in the season to improve establishment with low labor needs
- Ensure grazing cover after harvest and enable diversified and integrated agriculture
- Increase soil health, reduce need for fertilizer, weeds

https://www.earthsense.co/home
Fig. 1. Dealer offerings of sensing-related technologies over time. 2024 are projections.

Source: Croplife-Purdue University Precision Agriculture Dealership Survey

2021 Precision Agriculture Dealership Survey
https://www.croplife.com/?s=Precision+Agriculture+Dealership+Survey
Using AI to Reduce and Optimize Labor for Livestock Production

Computer Vision to Support Labor Needs in Commercial Animal Production Systems

- “Eyes” on animals more of the time
- Early identification of animal care needs
  - Illness
  - Lameness
  - Thermal challenges
  - Facility maintenance needs
- Predicting status
  - Estrus
  - Parturition
- Tracking animal growth and development
  - Nutritional needs
  - Market timing
Likely Drivers of Adoption of AI Technologies by Farmers

- Higher farm size
- Higher quality land
- Use of complementary technologies, computers
- Availability of skilled labor
- Relative advantage and perceived usefulness
- Education
- Attitudes
- Norms/peer pressure

**Farm characteristics**
- Farm size
- Biophysical conditions
- Land use
- Use of complementary technologies
- Land ownership
- Labor availability
- Livestock ownership
- Farm succession

**Operator characteristics**
- Education
- Age
- Farming as the main occupation
- Income
- Computer use
- Off-farm income
- Farming experience
- Innovativeness
- Knowledge & capacity
- Risk preference

**Interactions**
- Consultants
- Extensions
- Farmers' associations or other organizations
- Technology providers
- Other farmers
- Contractors
- Events (trade shows, workshops)
- Information sources

**Institution**
- Subsidy/credit
- Laws and regulations
- Relative advantage (perceived usefulness)
- Complexity (ease of use)
- Compatibility
- Data safety
- Trialability
- Observability

**Attributes of technology**
- Perceived behavioral control
- Subjective norm
- Attitude

Shang et al., 2020
Potential Barriers to Adoption of AI Technologies

• Demonstrated ability to improve farming outcomes

• Data confidentiality, ownership and governance

• Loss of farmer control on farm management decisions

• High speed internet connectivity and access to computers

• Access to technical assistance

• Rapidly developing technologies, interoperability of components
Artificial intelligence-enabled capabilities that will bring value to agriculture over the next decade

- Potential to transform farm operations
  - Reduce need for human decision making, uncertainty
  - Improve predictability, farm efficiency and health
- Use of digital twins- to better understand functioning of the farm and effect of interventions
- Enable supply-chain traceability
Thanks!

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https://aifarms.illinois.edu/
https://i-farm.illinois.edu/

AIFARMS
Artificial Intelligence for Future Agricultural Resilience, Management, and Sustainability

University of Illinois, Urbana-Champaign
Robotics and AI for Sustainable, Equitable Agricultural Systems

Framing Platform and Workforce Development

- A decade in Silicon Valley
- Founding an Ag Tech Startup
- Farm-ng and the Amiga
- Collaborative innovation

USDA Agricultural Outlook Forum 2024
Started April 1st, 2020:
- Online farmers market, food hub
- 250 boxes / week
- 40+ farms, whole diet
- $750K+ gross over two seasons
farm-ng
Modular robots for every acre

USDA Agricultural Outlook Forum 2024
Amiga
An electric robotic tractor.

Battery powered, light-weight, software defined vehicles will transform agricultural practices.
farm-ng
est. 2020

Venture Backed:
$16m Raised to Date

Ethan Rublee | CEO
Cofounder, Industrial Perception (Acq. $GOOGL)
Cofounder, Arraiy (Acq. $MTTR)

Claire Delaunay | CTO
VP of Engineering, Nvidia
VP of Engineering, Uber
Cofounder, Otto (Acq. $Uber)

30+ People
Manufacturing, Engineering, Sales, & Farmers

150 Robots Produced
70 Customers
Farmers, Research, Education
Broad adoption across research and education in agriculture.
Rapid User Onboarding and User App Development
Mature Ecosystem for Plant Science

flexible data collection platform

PSA-developed apps
Order your Amiga today at farm-ng.com

Contact sales@farm-ng.com for more information.
Move to Questions for Panelists