Collaborative Teams of Heterogeneous Robots for Agricultural Applications

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Advancing the Science of Autonomy

- Robotics
  - Small agricultural robots
  - Unmanned Aerial Systems
- Collaborative – Robotics
  - Learning from Human demonstrations
- Field Intelligence:
  - Machine learning
  - Neural Networks
- Adaptive Autonomy
  - Adaptive control
  - Reinforcement Learning

Group: 1 Research Faculty, 1 Postdocs, 2 Research Engineers, 6 PhD students, 3 MS, 4 research assistants
High Throughput Phenotyping

- Phenotyping: Relating genetics to plant traits
- Critical to efficient and productive breeding
- Currently labor intensive
Energy Department Bets $30 Million On More & Better Biofuel, With Robots (& Drones)

June 19th, 2015 by Tina Casey

The Energy Department has just announced a whopping $30 million round of projects for biofuel research, aimed at the transportation sector. We’ve been on a biofuel binge all week but this really tops them all in terms of cutting-edge technology and, yes, robots are involved.

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University of Illinois awarded $3.1 million to develop all-terrain rovers for high-throughput field phenotyping

Research to accelerate crop breeding for increased yields

CARL R. WOESE INSTITUTE FOR GENOMIC BIOLOGY, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

This self-driving robot from U. of I. could shape the future of farming

tools to find important patterns.”
Herbicide Resistant Weeds!

- Examples: 5-way multiple resistant Waterhemp and Palmer Amaranth
- Current cost 5-6 Billion, and on the rise!
- Mechanical control is the only evolutionarily sustainable way
Where are the ag robots?

Main challenges:
- Autonomy
- Cost
- Ease of use
Compact Low-Cost UAS are Practical

A plug-and-play autopilot designed to work across several aerospace vehicles.

• Widely adopted consumer systems are low-cost, simple, and multi-purpose
Overview of Inversion Based MRAC

- Approximate inversion model $\hat{f}$
- Design a pseudocontrol $\nu$ to minimize the tracking error: $e = x - x_{rm}$

\[ \dot{x} = \hat{f}(x, u) + [f(x, u) - \hat{f}(x, u)] \]

- Combined pseudo-control action:
  \[ \nu = -Ke + \dot{x}_{rm} - \nu_{ad} \]

- Tracking error dynamics
  \[ \dot{e} = Ae + B(\nu_{ad} - \Delta) \]
Adaptive Systems
Plug-and-Adapt Autonomy

Recorded Flight Data Replay
(First Three Maneuvers)

Left: CL-MRAC
Right: PID

GP-MRAC: Disturbance Adaptation

- Grande, Chowdhary, How JAIS 2014 (Experimental Validation of Bayesian Nonparametric Adaptive Control using Gaussian Processes)
- GP-MRAC learns how the disturbance affect forces on the UAV
Collaborative Robotic Teams
Can Co-robots Learn to Teach?

Brought to you by
Distributed Autonomous Systems (DAS) LAB at UIUC
in collaboration with
Comparative Psychology Laboratory at Oklahoma State University.

Harshal Maske, Emily Kieson, Girish Chowdhary, and
Charles Abramson
Smart Robotic Teams for Agriculture

Integrative Research Goals:
• Autonomy
• Multi-robot collaboration
• Cost
• Seamless Human-Machine interaction
autonomous Path Following and obstacle avoidance

8x speed
Sensors
Autonomous Testing in Sorghum plots
2017
Lane keeping with Convolutional DNN
Corn Counting
Broad Leaf Weed Detection
Deviance Detection from Aerial Images

From take-off to actionability, in 20 minutes or less!
UIUC Team

- Deep robotics and crop-science expertise
- Successful prototypes and modular Cyber-Physical systems
- 16 top 5 ranked engineering programs
- Highly accomplished faculty: USDA – ARS chairs to Fellow of the Royal Society

Institute of Genomic Biology  Coordinated Science Lab
Team work!

• Team:
  – Postdoctoral associates: Erkan Kayacan
  – Postdoctoral Fellow/Research Assistant Prof: Chinmay Soman
  – PHD: Allan Axelrod, Girish Joshi, Harshal Maske, Anay Patnaik, Dennis Osipychev, Joshua Whitman
  – MS: Anwesa Chaudhari, Beau Barber, Hunter Young
  – Research Engineers: Nolan Replogle, Sri Vuppala
  – Research Assistants: Ben Thompson, Volga Karkaus, Zang Zhongzhong
  – Visiting fellow: Akihiro Higuti (University of Sao-Paulo Brazil)

• Collaborators:
  – Sertack Karaman, AFOSR DDDPSA
  – Prabhakar Pagilla, Christopher Crick, and Charles Abramson, NSF NRI
  – Steve Long, Carl Bernacchi DOE-ARPA-E
  – Adam Davis, Weeding swarmbots

• Support
  – ARPA-E
  – AFOSR Young Investigator Award, James Lawton
  – AFOSR DDDAS, Frederica Darema
  – NSF NRI
  – DOE
  – NASA

EARTHSENSE
Agricultural Intelligence

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Where to from here?

• Ag robots are here to stay
• Challenges
  – Cost
  – Autonomy
  – Reliability
  – Ease of Use
• What would drive adoption?
Backup