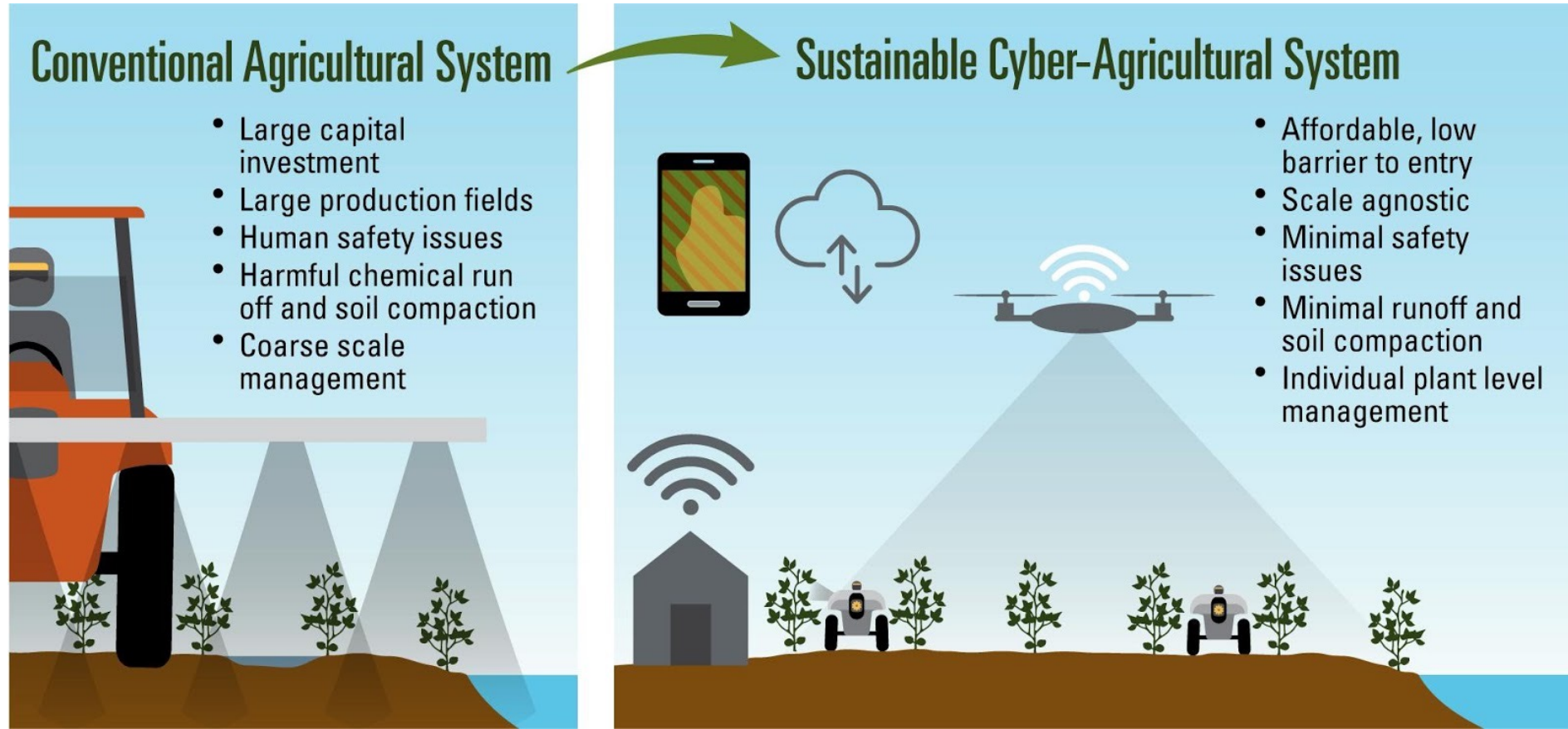# CPS: Frontier: Collaborative Research:

COALESCE: COntext Aware LEarning for Sustainable CybEragricultural systems

Soumik Sarkar

Iowa State University

Frontier Panel, CPS PI Meeting
11/08/2022

The COALESCE Vision

Goal: Disrupt the current agricultural practices with CPS innovations to enhance efficiency, resiliency, sustainability and autonomy
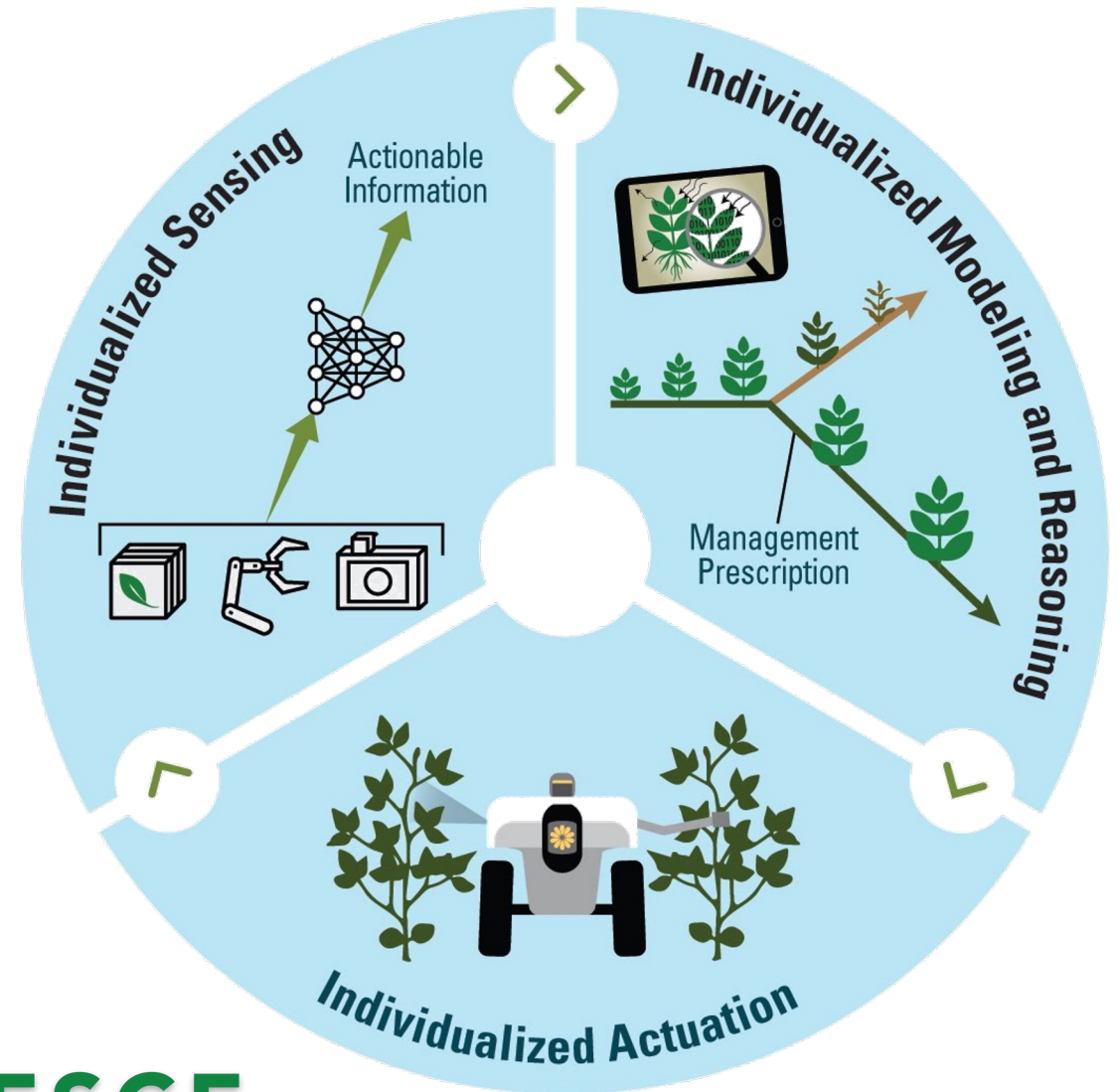

Conventional Agricultural System
- Large capital investment
- Large production fields
- Human safety issues
- Harmful chemical run off and soil compaction
- Coarse scale management

Sustainable Cyber-Agricultural System
- Affordable, low barrier to entry
- Scale agnostic
- Minimal safety issues
- Minimal runoff and soil compaction
- Individual plant level management

COALESCE
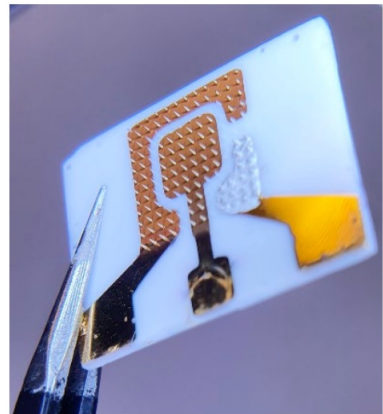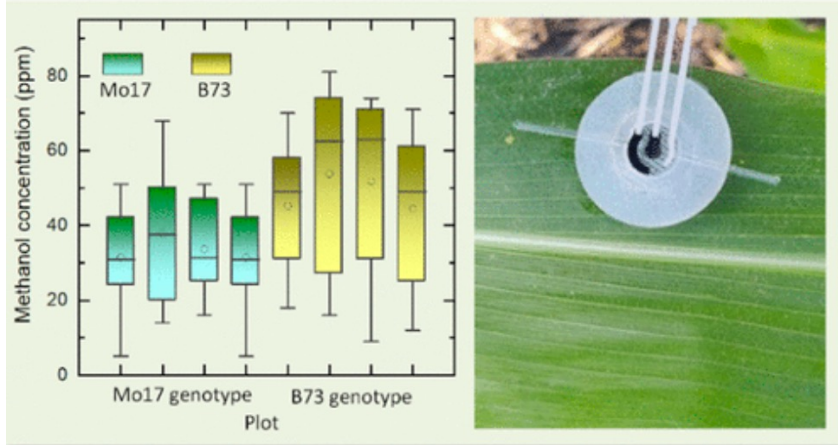
Scientific frontiers in CPS

Bio-physics aware ML

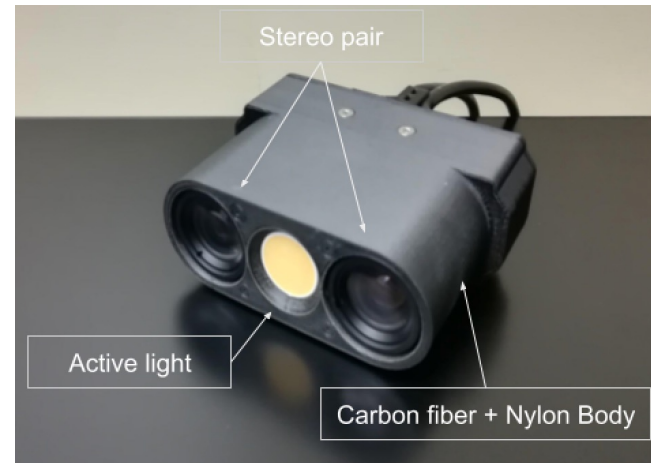**Decision-control-actuation using individualized sensing/modeling**

Coordinated teams of dexterous robots
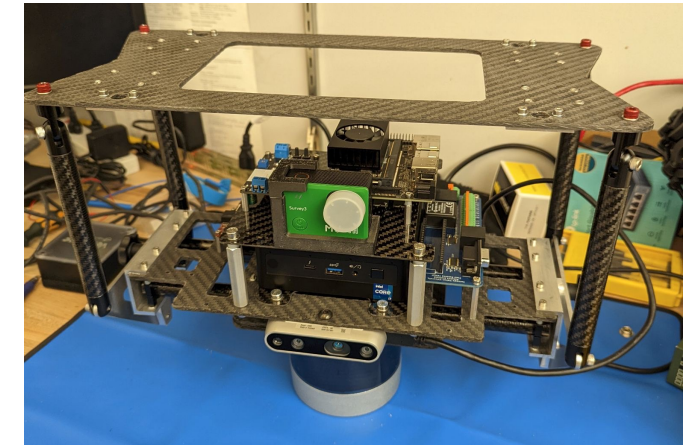
Multimodal sensing

In Planta Sensing

Advanced Imaging

- sync circuitry
- raster scanning laser projector
- rolling shutter CMOS cameras
- Stereo pair
- Active light
- Carbon fiber + Nylon Body
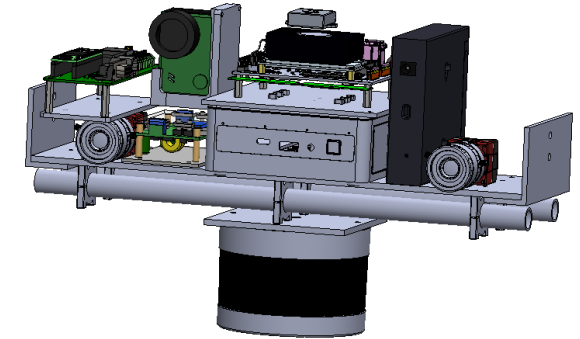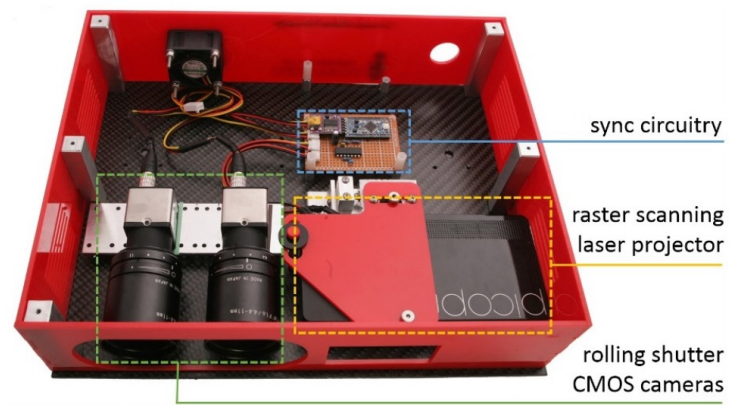
Multi-modal Payloads

Multi-platform sensing

Aerial / Satellite
Multi-modal Imaging

In Situ Cameras

Robotic Imaging

Individualized plant modeling

- Preliminary exploration of data-set creation
- Hyper controlled environment vs Field conditions
- Future weather conditions vs current conditions
- Various water availability conditions
- Collect time sequence of multi-modal data (RGB, Thermal, 3D point cloud, Hyperspectral bands, soil moisture, environment)
- Streamline collection, curation, and dissemination

COALESCE
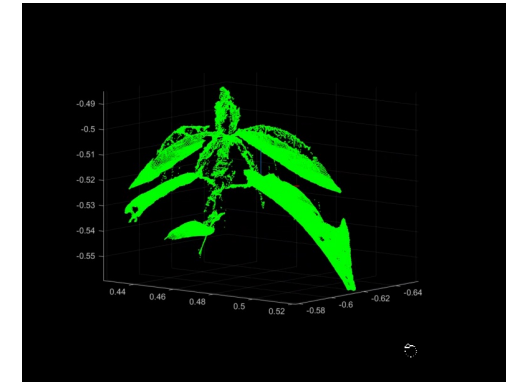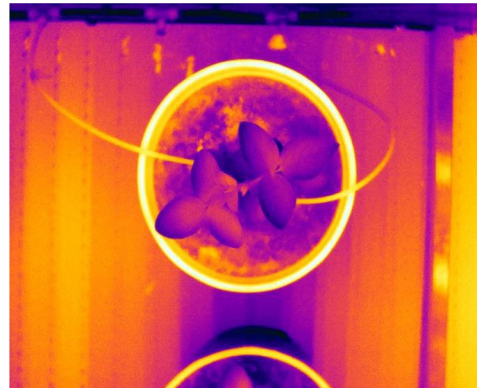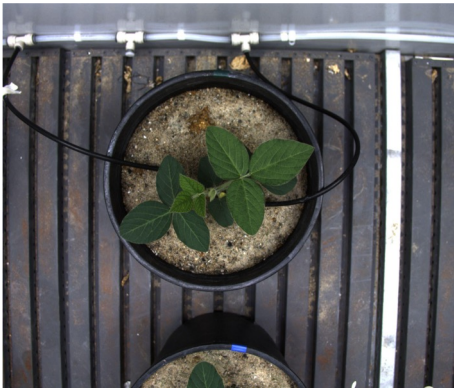
UAV RGB measurements
UAV Thermal measurements

Ground RGB measurements
Ground ASD (spectra) measurements

Ground TLS measurements

Decision Support - AR/VR/XR

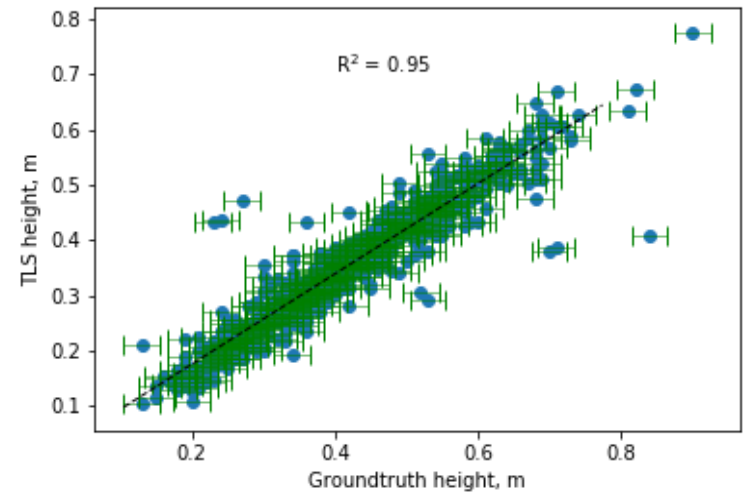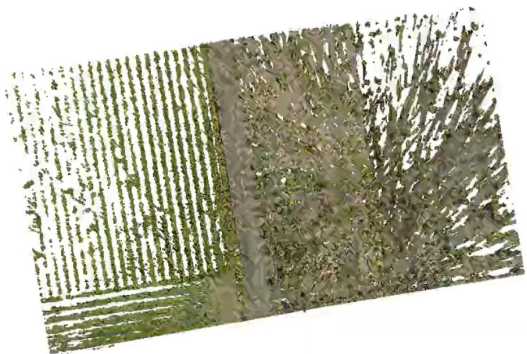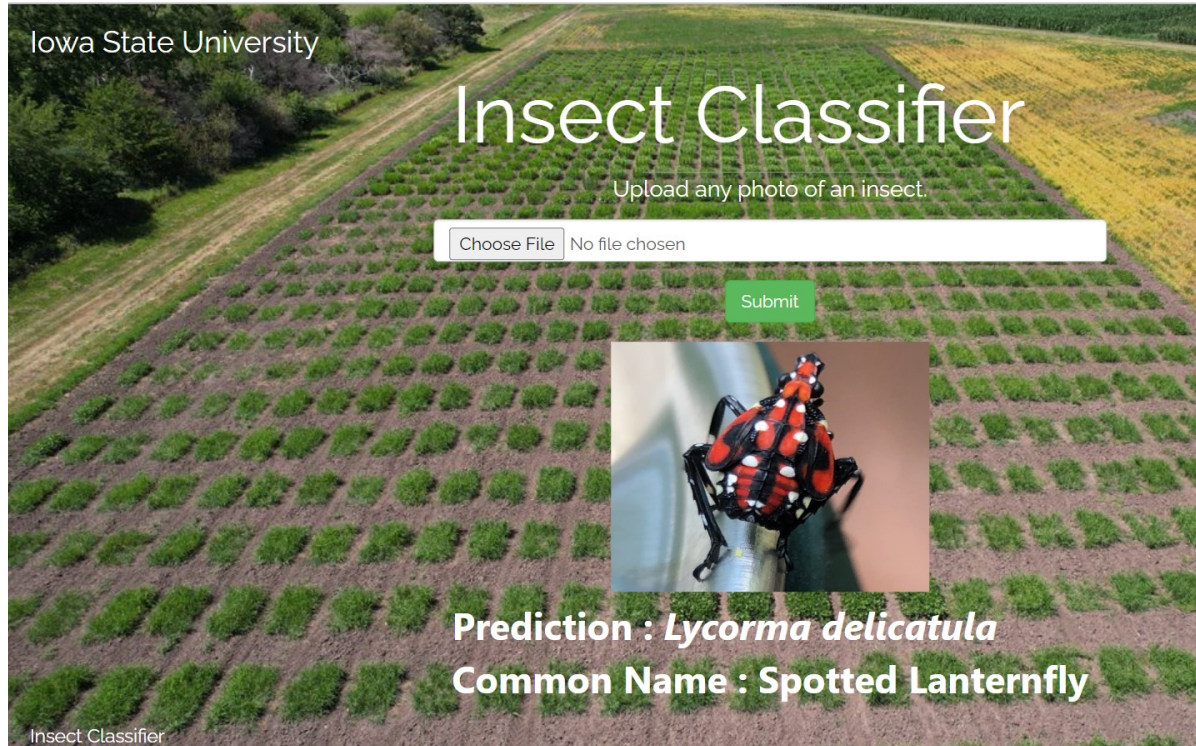# Precise actuation – mitigation of insect pests

The fall armyworm outbreak of 2021 - Marched north into the Midwestern states like Illinois, Indiana, Ohio and Iowa from southern states like Texas and Florida

Decision support – Mobile App

Iowa State University
Insect Classifier
Upload any photo of an insect.

Choose File | No file chosen

Submit

Prediction : *Lycorma delicatula*
Common Name : Spotted Lanternfly

Insect Classifier

7-spotted: 98.23   Variegated: 94.09   Transverse: 92.16

Spotted Lantern Fly Nymph

Source: https://www.nps.gov/vafo/learn/nature/lanternfly.htm

Spotted Lantern Fly Adult

Source: https://en.wikipedia.org/wiki/Spotted_lanternfly

Lygus Nymph

Lygus Adult

Predator   vs   **Pest**

- iNaturalist data set created by citizen scientists

- Self-supervised pretraining with 2M unlabeled data

- Supervised fine-tuning with 660K labeled data

- >90% mean per class accuracy on >2500 insect classes

- Stress-tested 'in the wild'

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Closing the Sensing-Actuation Loop

1. Base camera surveys shrub for zones where bugs thrive: flowers, foliage etc.

2. Soft arm maneuvers to place tip camera in these zones. Images are fed to the onboard/cloud computing system

3. If harmful bugs are detected, the arm visually servos to capture hi-res images

4. The tip nozzle sprays chemicals at prescribed targets

5. Alternate actions: sampling parts for further inspection, mechanical mitigation etc.
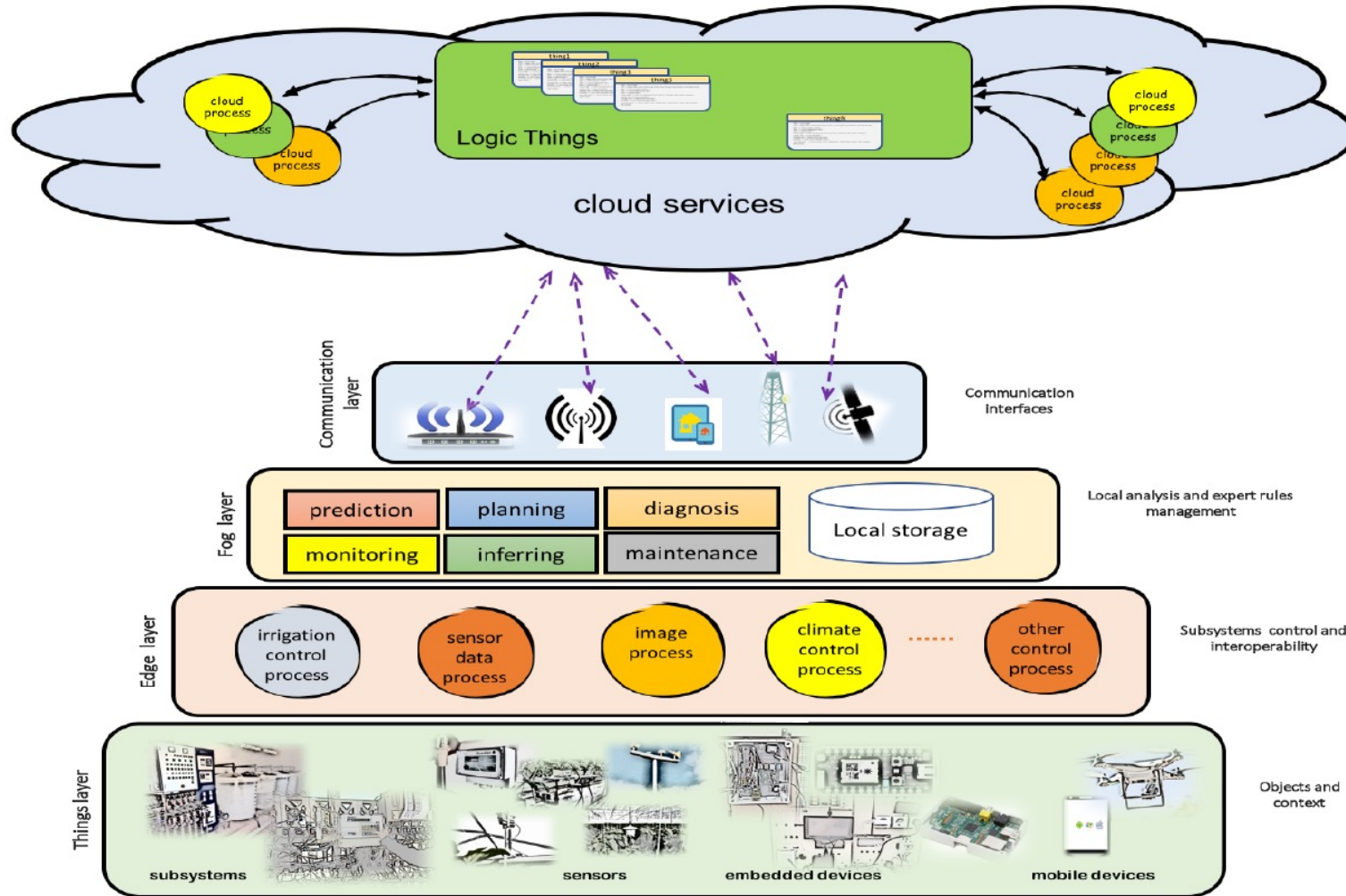
Images as seen from the tip-camera

Challenges
- Obtaining stable images from tip camera
- Soft arm controls and visual servoing
- Path planning through and around obstacles

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Looking through the robot's eye

Decentralized Learning

- Decentralized learning without central parameter server

- Robust, resilient, applicable under communication constraints

- Challenges – non-IID data, communication overhead, scale-up

https://www.mdpi.com/1424-8220/18/6/1731

COALESCE

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Education and outreach

IOWA STATE UNIVERSITY
College of Engineering News

News Home | Students | Research | Academics | Departments ⌄ | Alumni | Podcasts | News Archives

New cyber-physical systems minor leverages industry ties to enhance student futures

April 21, 2021 • John Burnett-Larkins

A first-of-its-kind curriculum in Iowa will soon be available to students in Iowa State University's College of Engineering – and will help prepare them for a cutting-edge area of technology that's part of what has been deemed "the fourth industrial revolution."
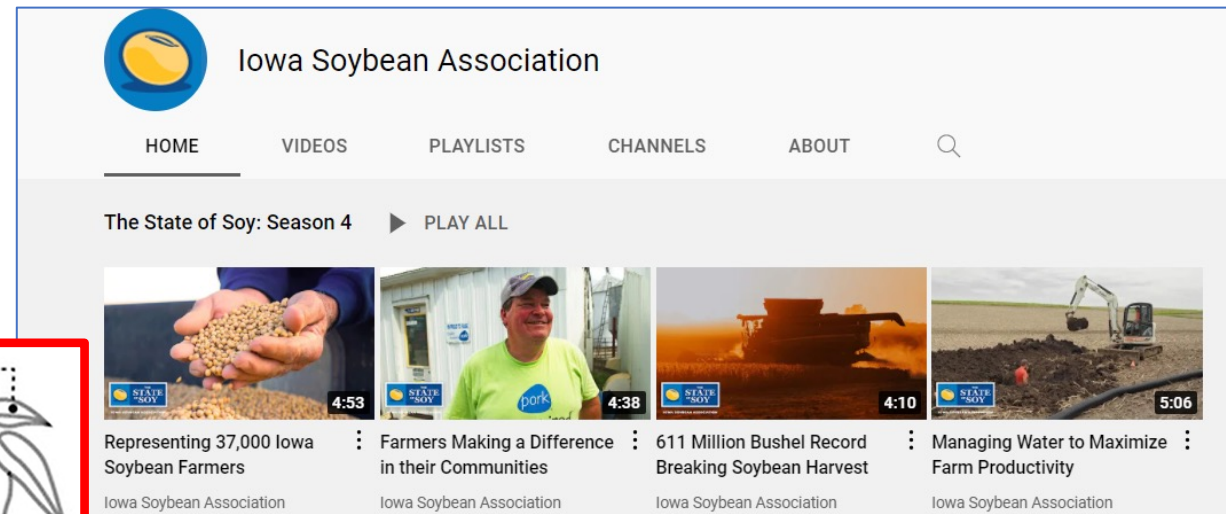
Informal learning

YouTube videos for farmers and general public

WOMEN IN AG & AI

INSECT APP

DIGITAL TWIN

New CPS minor at Iowa State

Sarkar is leading the CPS minor launch in Fall 2021 at the undergraduate level

Iowa Soybean Association

HOME | VIDEOS | PLAYLISTS | CHANNELS | ABOUT

The State of Soy: Season 4 ▶ PLAY ALL

| 4:53 | 4:38 | 4:10 | 5:06 |
Representing 37,000 Iowa Soybean Farmers — Iowa Soybean Association
Farmers Making a Difference in their Communities — Iowa Soybean Association
611 Million Bushel Record Breaking Soybean Harvest — Iowa Soybean Association
Managing Water to Maximize Farm Productivity — Iowa Soybean Association
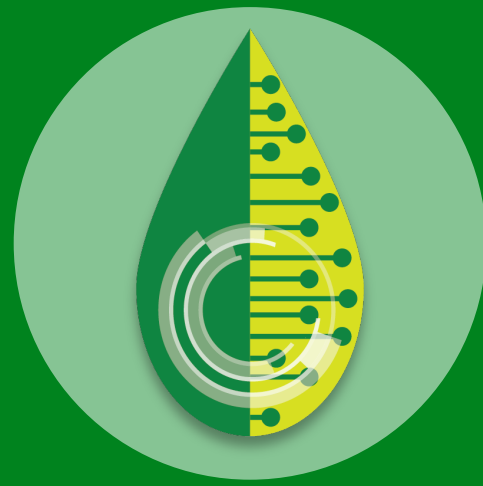
Farmer outreach

Iowa Soybean Assoc, Field tours

COALESCE

Knowledge dissemination

An increasing world population, coupled with finite arable land, changing diets, and the growing expense of agricultural inputs, is poised to stretch our agricultural systems to their limits. By the end of this century, the earth's population is projected to increase by 45% with available arable land decreasing by 20% coupled with changes in what crops these arable lands can best support; this creates the urgent need to enhance agricultural productivity by 70% before 2050. Current rates of progress are insufficient, making it impossible to meet this goal without a technological paradigm shift.

MLCAS
- We continue to organize the flagship event of the CAS community
- 100+ participants each year
- CAS competition
- Special issue in *Plant Phenomics*

AIAFS
- AI for Agriculture and Food Systems workshop at the 2022, 2023 AAAI conference
- AI/ML, robotics, sensing, cyber-physical systems, agriculture engineering, plant sciences, genetics, and bioinformatics

Thank you!

For more information visit: https://coalesce.me.iastate.edu/