IoT4Ag News | Spring 2022

Letter from the Director

Welcome to the National Science Foundation Engineering Research Center (ERC) for the Internet of Things for Precision Agriculture (IoT4Ag) and our inaugural newsletter. IoT4Ag was established in September 2020, with $26 million in support from the NSF ERC program over the next 5 years. Since then, we have launched 30+ cutting edge research projects spanning from biodegradable sensors to underground wireless power delivery. At the same time, we've built online tools to collaborate and advance our research, education, inclusion, and innovation goals and brought agricultural technology skills and experience to hundreds of K12 and university students. As 2022 begins, we are excited to share the Center's programs across the ERC pillars of convergent research, workforce development, diversity & culture of inclusion, and innovation ecosystem.

The mission of the IoT4Ag ERC is to create and translate to practice Internet of Thing (IoT) technologies for precision agriculture and to train and educate a diverse workforce of agricultural technologists. If you are passionate about enabling the future of food systems through digital, AI, and precision agriculture technologies, we invite you to reach out to us as a research collaborator, as an educational, industry, or government partner, or even as a future student or postdoc researcher. We'll need diverse partnerships and professionals to achieve our vision of addressing the societal grand challenge of food, energy, and water security through technological transformation.

We look forward to updating you each quarter with the highlights, successes, and opportunities in our research, education, and innovation. Follow along with more updates at IoT4Ag.us and on Twitter at @IoT4Ag.

Dr. Cherie Kagan

IoT4Ag

The Internet of Things for Precision Agriculture
an NSF Engineering Research Center

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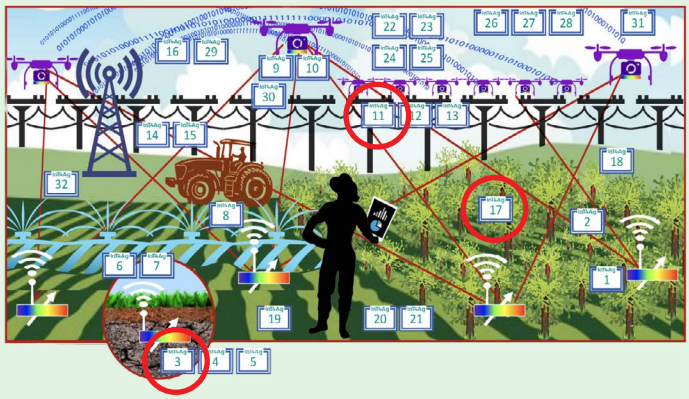
PARTNER INSTITUTIONS

Penn University of Pennsylvania | Purdue University | University of California Merced | UF University of Florida | NSF

RESEARCH HIGHLIGHTS

PROJECT MAP

A visualization of the the 32 IoT4Ag research projects initiated to-date.



WATER STRESS DETECTION SENSOR

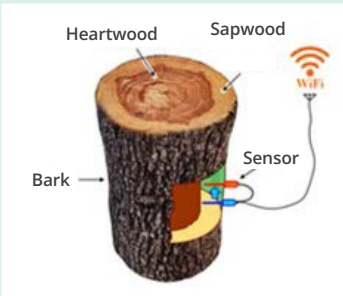
From the Ehsani group at the University of California, Merced

PROJECT 17

We developed a **new low-cost, wireless sensor that can monitor tree trunks' water content and sap flow**. This sensor can be used to predict tree water stress. The sensor was used to collect data during the entire growing season in a pistachio orchard.

Wonderful Pistachio is interested in testing this sensor in their orchard this year. In addition, this sensor will be tested and compared against other commercially available sensors by an independent researcher.

Currently, the whole of California is under severe drought for the second year in a row. **Precision and efficient irrigation systems require cost-effective techniques to assess water stress and this sensor could help increase irrigation efficiency.**



BIODEGRADABLE, CELLULOSE BASED, SOIL MOISTURE SENSOR

From the Turner group at the University of Pennsylvania

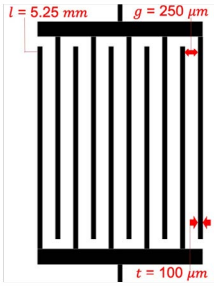
PROJECT 3

We study biodegradable, inexpensive, wireless sensors that can operate below the soil surface. These sensors can be densely deployed across agricultural fields to locally measure soil properties to detect conditions that **predict future crop stress and allow for early intervention** to improve crop yield.

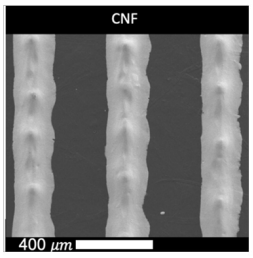
We've developed a **biodegradable moisture sensor using a cellulose nanofiber (CNF) substrate**, which is compatible with the passive, wireless sensor architecture being developed for underground sensing.

By observing soil conditions that lead to future crop stress, **growers can intervene to increase crop yields while preventing overuse** of fertilizer and water.

Moisture Sensor Design



Scanning Electron Microscope Image



WIRELESS RECHARGING OF DEEP-BURIED SOIL SENSORS

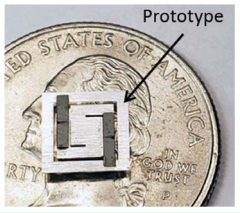
From the Arnold group at the University of Florida

PROJECT 11

We are working on **wireless power technologies** to deliver wireless power through metal structures or wet, muddy soil. Current wireless charging technologies generally only work through air.

In recent field experiments, we have demonstrated wireless **power delivery to wireless power receivers buried 5 cm to 50 cm underground.**

The ability to recharge underground sensors and electronics will help a**ccelerate deployment of smart IoT agricultural networks** by minimizing the labor of unburying and replacing batteries.



WORKFORCE DEVELOPMENT

SHARING RESEARCH AND PRACTICE:
IoT4Ag Virtual Boot Camp

During the fall of 2020 and spring of 2021 semesters, IoT4Ag organized a bi-weekly training series. These trainings were instrumental in creating a space for information exchanges to spur collaboration.

Faculty and industry partners presented on topics such as:

- Plant and Soil Science
- (Un) Conventional Sensors
- Agricultural Communication
- Machine Learning and Artificial Intelligence
- Agricultural Economics
- Decision Agriculture & Controls
- Energy Harvesting Technologies
- Robotics
- Imaging and Sensor Fusion

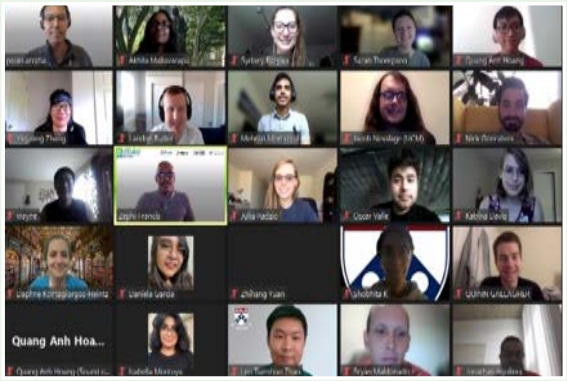
EXPANDING THE CURRICULUM:
New Course Developed

IoT4Ag faculty have been working diligently to develop and modify courses for students interested in precision agriculture. The first new course, *Internet of Things Sensors and Systems*, was launched and taught by Dr. Cherie Kagan this semester (Spring 2022). Hosted at the University of Pennsylvania, the course drew 39 students from Penn, UC Merced, and Florida.

REACHING THE NEXT GENERATION:
IoT4Ag in Local Schools

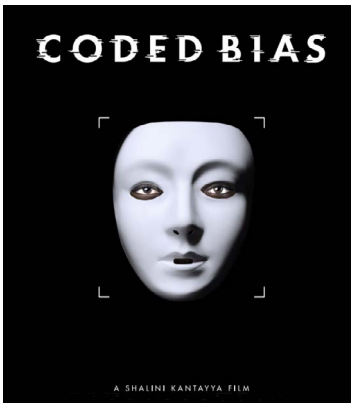
A group of IoT4Ag members from Penn visited Lower Merion High School and taught students how to control small robots and use sensors. Our outreach efforts are designed to pique students' interest in engineering and to equip them with new skills.

PATHWAY TO PH.D. PROGRAM (PPP)



IoT4Ag offered our first annual Pathway to Ph.D. Program (PPP) virtually on September 25 and 26 to 20+ participants and mentors. PPP is a hands-on, 2-day workshop designed to introduce underrepresented undergraduate students to the graduate school admission process. Additionally, the program provides an overview and opportunity for participants to complete components of the National Science Foundation Graduate Research Fellowship Program. We look forward to tracking the success of this Inaugural group, as we prepare for the 2022 PPP.

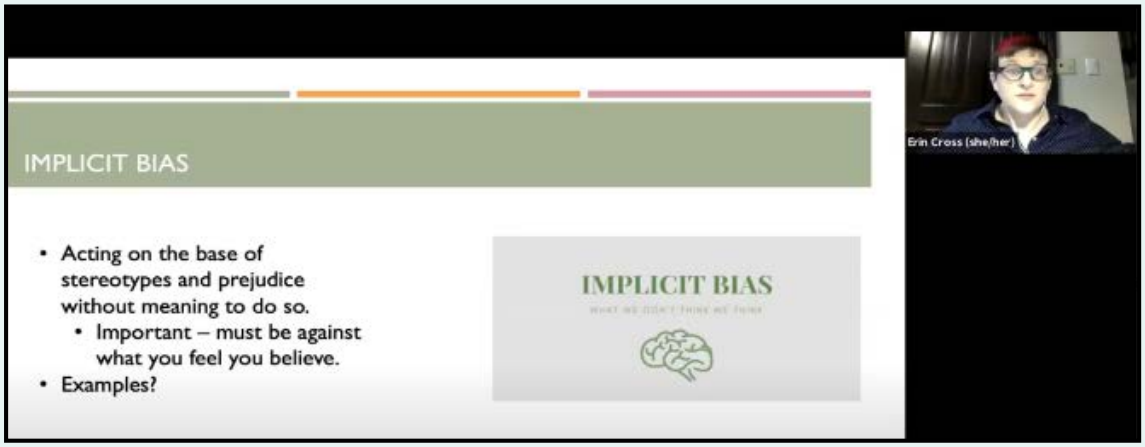
DIVERSITY & CULTURE OF INCLUSION



CODED BIAS: FILM SCREENING AND PANEL DISCUSSION

On June 9, 2021, IoT4Ag hosted a virtual screening and panel discussion on the film Coded Bias. The film highlights algorithmic bias against racial and gender characteristics, leading to artificial intelligence (AI) system misidentification and other negative outcomes. For instance, viewers saw that facial recognition software did not identify dark-skinned faces as accurately as light-skinned faces. Our panelists (Paulo Arratia, Dania Matos, and Sherine Obare) discussed ideas on how scientists and engineers can create and expand technology without perpetuating bias against marginalized groups.

IMPLICIT BIAS TRAINING FOR MEMBERS



In February and March of 2021, Dr. Erin Cross (Director of Penn's LGBTQ Center) facilitated a diversity and culture of inclusion training for our members. The goals of the training were to raise awareness of our own biases that we all hold, and to identify solutions to address discriminatory behavior. A program evaluation of the training indicated that 48% of respondents reported knowledge increase on the topic of implicit bias. All IoT4Ag members were required to complete this training.

CHECKING IN WITH STUDENTS AND POSTDOCS

Each year, the DCI leadership team has several structured check-ins with students and postdocs. The objectives of the check-ins are to connect students and postdocs with DCI leaders, discuss DCI topics, and create camaraderie through social activities. At the Summer check-in, we discussed the benefits of mentoring and inclusive mentoring practices, with the goal of developing cross-campus mentors. Our Fall check-in was a workshop on ethics in research and tech facilitated by Dr. Eugenio Zaldivar (Santa Fe College). This Spring, students had a chance to discuss and make recommendations based on the first annual Graduate Student Survey (GSS).

Out of 30 GSS respondents,

said IoT4Ag has significantly improved their collaboration skills.

believe IoT4Ag actively promotes diversity and advances inclusion.

INNOVATION ECOSYSTEM

We are pleased to welcome these 24 inaugural members of the IoT4Ag Industrial Practitioner Advisory Board (IPAB). Members of the IPAB represent a range of stakeholders in the innovation ecosystem and value chain for precision agriculture technologies, including both government and commercial organizations. These range from start-ups developing enabling technologies to industry leaders supporting the systems integration of agricultural technologies to government organizations providing the end-user perspective throughout the technology design and development process.

In addition to helping set the strategic direction of IoT4Ag, members of the IPAB gain early access to results of research conducted by the Center and have the opportunity to sponsor specific research projects and recommend patent application filings for technologies developed through the Center. Members also participate in knowledge exchange and educational programs, and have opportunities to meet and recruit students who are passionate about careers in precision agriculture. The IPAB provides access to technical experts in the fields of agronomy; sensor, energy, and communication technologies; robotics; information and decision systems; precision agriculture; and food security

AGERpoint
AgSensor Solutions
AGR Augean Robotics
agribugs
Ben Franklin Technology PArtners
cdfa California Department of Food & Agriculture
Corteva agriscience
Cotton Incorporated
Florida Department of Agriculture and Consumer Services
Headwall
Indiana State Department of Agriculture
John Deere
Matrix
MicaSense
Milano Technical Group Inc
nanoλ
OnePlanet Research Center
Opti-Harvest Better Light Makes Better Fruit™
pennsylvania Department of Agriculture
SeekOps
SunSouth
treeswift
USGA
WHIN

A summary of current IPAB members and the benefits of participation can be found at:
iot4ag.us/innovation-ecosystem/ipab

FEATURED PUBLICATIONS

SPECIAL REPORT

THE INTERNET OF THINGS FOR PRECISION AGRICULTURE (IOT4AG)

Cherie R. Kagan, David P. Arnold, David J. Cappelleri, Catherine M. Keske, Kevin T. Turner, Special report: The Internet of Things for Precision Agriculture (IoT4Ag), *Computers and Electronics in Agriculture*, 2022, 106742. ***Citation link***

PROJECT 11

A WIRELESSLY RECHARGEABLE AA BATTERY USING ELECTRODYNAMIC WIRELESS POWER TRANSMISSION

S. E. Smith, M. A. Halim, S. T. Chyczewski, A. A. Rendon-Hernandez, and D. P. Arnold, "A wirelessly rechargeable AA battery using electrodynamic wireless power transmission," *Energies*, vol. 14, no. 9, 2368, 14 pages, Apr. 2021. ***Citation link***

PROJECT 16

FAST POSITION-AIDED MIMO BEAM TRAINING VIA NOISY TENSOR COMPLETION

T. H. Chou, N. Michelusi, D. J. Love and J. V. Krogmeier, "Fast Position-Aided MIMO Beam Training via Noisy Tensor Completion," in *IEEE Journal of Selected Topics in Signal Processing*, vol. 15, no. 3, pp. 774-788, April 2021, doi: 10.1109/JSTSP.2021.3063837. ***Citation link***

WORKFORCE DEVELOPMENT

ENTREPRENEURIAL TALENT BUILDING FOR 21ST CENTURY AGRICULTURAL INNOVATION

Yoon BK, Tae H, Jackman JA, Guha S, Kagan CR, Margenot AJ, Rowland DL, Weiss PS, Cho NJ. Entrepreneurial Talent Building for 21st Century Agricultural Innovation. *Acs Nano*. PMID 34269059 DOI: 10.1021/acsnano.1c05980. ***Citation link***

LOOKING AHEAD