CPS for Agriculture Mini Workshop

NSF Cyber Physical Systems PI Meeting
November 21, 3:45-5:45pm
Jefferson Meeting Room
Crystal Gateway Marriot, Arlington VA

3:45pm Introduction (George Kantor)
3:47pm Remarks from Steven Thomson (NIFA CPS Program Director)
3:55pm Manoj Karkee: AI, Robotics and CPSs for Agriculture
4:10pm Robin White: Leveraging Animal Nutrition to Enhance Sustainability
4:25pm Nuwan Wijewardane: CPS-enabled Soil Information System for Digital Agriculture
4:40pm Ryan Williams: Large-Scale Monitoring, Expert Input, and the Ecological Impact of Autonomy in Agriculture
4:55-5:25pm panel discussion (all speakers, moderated by George)
5:25-5:45pm open discussion and networking

Manoj Karkee

AI, Robotics and CPSs for Agriculture

- What: make and implement farming decisions with increasingly desirable outcomes over time
- Why: assist in producing **more/better with less**
- Approach: use sensing and AI to understand what is going on inside a plant, and then make decisions based on that.
- Cutting edge:
  - Robotics for: pruning, harvesting
  - Improve vision systems, understanding the entire canopy
- Future:
  - Exploit systems approaches, exploit multi disciplines, including socioeconomic
  - Optimize cost and robustness
  - Go from data to information: from “what is there” to “why is it happening”
  - Connectivity and integration

Robin White:

Leveraging Animal Nutrition for Sustainability

- High level points:
  - Leveraging animal source foods is a key area to improve for sustainability
  - Animals are interesting from a controls perspective because they are sentient
- Key results:
  - Cow stomach fermentation: monitor fermentation in cow stomachs, figure out in real time what is limiting the fermentation, then feed the cow nutrient mix appropriately
    - This is where sentience adds complexity: we can't control the cow!
  - Closed environmental control: find ideal microclimates that animals prefer (distributed sensing) and control environment to match their preferences
  - Grazing systems: understand nitrogen movement through grazing pastures. How do animals contribute to nitrogen runoff? Distributed sensing plus animal monitoring helps to understand this.
- Frontiers:
  - Animals, systems, environments; and how they interact with humans. Multiple feedback loops at every level.
  - Policy impacts, ethical considerations.
  - Human-animal interactions, especially considering animal sentience

Nuwan Wijewardane

CPS-enabled Soil Information System for Digital Agriculture

- Predict and control present and future based on present and past data
- CPS enabled: measure things, send to cloud, process, then send down actionable information (prescription maps, etc.)
- VisNIR / MIR spectral libraries to model soil properties: it works! And can be used at different depths
- Also can incorporate surface sensing. There is good correlation of depth with P,TN/TC, but accuracy is limited by available data sets.
- Challenges looking forward:
  - Need more good data sets
  - Model robustness
  - Reliable field sensors
  - Complex ag systems
  - Adoption
  - Security

Ryan Williams

Large-Scale Monitoring, Expert Input, and the Ecological Impact of Autonomy in Agriculture

- Applying multiple robots and robot coordination in ag at scale.
- Precision grazing at large scale is a challenging and important monitoring problem.
- Current results: perceive forage quality.
  - The big questions is when do we sense in order to maintain a good estimate.
  - Then when you send the cows there, it changes the spatiotemporal process.
  - Current approach, using UAV teams and LIDAR, give about 8% error
- Future
  - Input existing expert models (e.g., PHYGROW), how to combine with big data
    - Idea: decouple spatial and temporal aspects, use expert for temporal, GP for spatial
  - Evaluate ecological of autonomy: what do we optimize for?

Panel

- “Easy” problems: more rugged / less expensive sensors; better wireless connectivity; bigger better data sets.
- “Hard” problems: consider social and ecological feedback in ag systems; incorporate human domain knowledge.
- Potential 3-year “headlines” (ambitious but reachable goals)
  - More output with fewer inputs, especially labor
  - Make livestock ag 30% more efficient by controlling nutrition
  - Optimize production while considering socio-ecological factors (e.g. pollinator diversity)