Development of a Robotic Center Pivot for ML/AI Enabled Near-Field Sensing, Edge-Computing, and Control for Agricultural Experimentation “At Scale”

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OATS
Open Agriculture Technology and Systems

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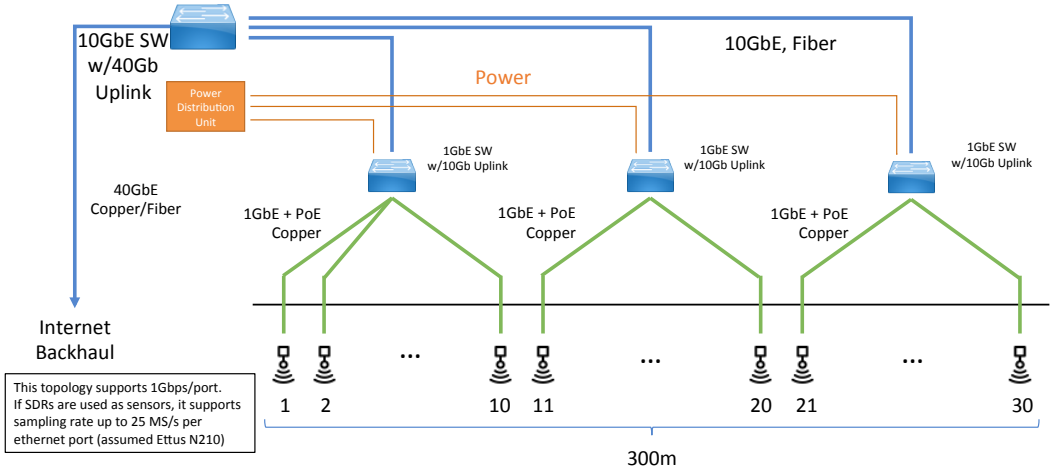
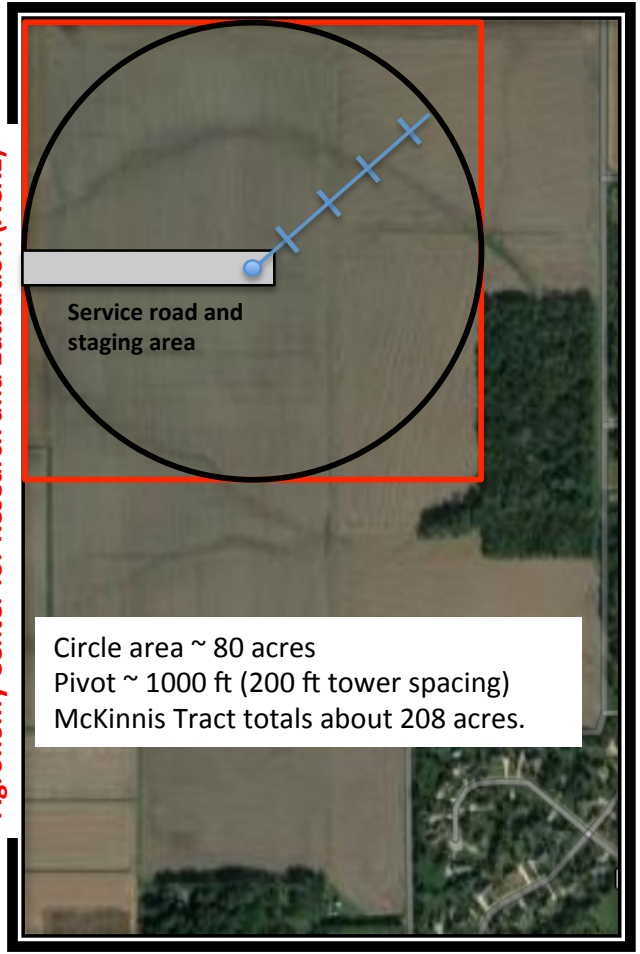
The Proposed Instrument

- Commercially available irrigation system as a moveable platform for:
  - + Sensing: soil, water, plant, micro-climate, robotic scouting and tissue sampling
  - + Actuation: water, fertilizer, crop protection, spot tillage or weeding
- The land below equipped with a dense drainage tile system instrumented for water and soil sensing, drainage control, underground comms.



This topology supports 1Gbps/port. If SDRs are used as sensors, it supports sampling rate up to 25 MS/s per ethernet port (assumed Ettus N210)



The Research Enabled

The Enabled Research Activities [1/3]

- Pheno-typing and management practice studies
  - Hyperspectral imaging
  - RGB imaging and video
  - Lidar, infrared
- Micro-climate studies
  - Heat, mass, and momentum transfers between organisms and the atmosphere
  - Greenhouse gas emissions from ag operations
  - Solar UV radiation and effects on crops

The Enabled Research Activities [2/3]

- Radar – conventional and synthetic aperture
  - + Ground penetrating for mapping soil layers, especially evidence of hardpan and compaction
  - + Soil moisture estimation
  - + At scale tomographic root imaging
  - + Lidar, infrared
- Robotics – joint control of gantry mounted robotic arms and the pivot assembly
  - + Weeding
  - + Insect scouting
  - + Targeted application of water, fertilizer, and/or herbicides

The Enabled Research Activities [3/3]

- mmWave and THz Sensing of crops and atmospheric gases, IoT4Ag style sensors
- Cornfield (Beans, wheat, pumpkins ⋯) as a system
  - Synchronized and simultaneous measurement (spatial and temporal) of all parameters
  - Study of system under or after stress event (drought, hail, insects, etc.)
  - Characterize the effect of hard constraints on applied water, nutrients, pesticides, etc.
  - Measure soil borne carbon over growing season
- Prove concepts of AI/ML at scale and in real time

How the Proposed Instrument Fits in the Puzzle

TERRAPHENOTYPING REFERENCE PLATFORM

Partner Institutions

- U. Arizona, U. Illinois, Saint Louis U., G. Washington U., Wash. U., K. State, Clemson
- D. Danforth Plant Science Center

Funding: ARPA-E

- > $10M, 2015 − 2020

Primary Use: Platform for phenotyping of sorghum as a bio-energy source; drought stress

Compare to TerraRef

- Order of magnitude larger in area
- Potential for actuation
- Deployable at much lower cost
- Sensing, comms, robotic innovations have the potential to impact farming practice, not just research
- Potential for lowering cost and democratizing “at scale” agronomic experimentation

Design of the Instrument Itself

The Pivot Instrument Is …

- Three sub-systems:
  - A nearly conventional irrigation pivot (precision application of water and water soluble crop treatments + sensing)
  - A data, sensing, robotic actuation pivot as a gantry (limited water, etc. application --- it provides power and high bandwidth wired networking and a standardized port for connecting experimental packages)
  - Earth buried sensing and instrumented drainage tile with wireless short range connection to the pivot for wireless power and sensor readout
- Think “minute” hand, “hour” hand on a clock − minute hand cannot pass the hour hand, but it is much faster.
  - Could have “minute” hand only … say in Indiana.

Pivot Instrument Design Considerations [1/2]

- Networking along the gantry (~300 m):
  - Several fiber strands and periodically placed power ports and ethernet connections (~10 m spacing)
  - Need to enable fixed fiber optic link to interface with rotating hub in the center pivot (mmWave short range wireless, optical rotary joint …)
  - Must operate in harsh environment and high temperatures
- Pivot drive design for the “minute” hand pivot. Forward/ backward and faster than conventional
- Pivot rotation point design for minute and hour hand
- High precision GPS at every tower

Pivot Instrument Design Considerations [2/2]

- Instrumented and Controllable Tile Drainage System
- Beta Instruments and Control Experiments
  - “Plug-and-play” compatible with research designed sensor packages … standard interface
  - Back of the envelop rate calculations. With pivot gantry covering 16 acres per hour ~ 1 Gbps for RGB Flea cameras, Velodyne VLP 32C, Headwall VNIR, and a thermal camera – compared to Purdue pheno-rover machine. Likely need considerably more bandwidth, but it is feasible.
- Agronomy: experimental plot designs for using such instrument

ML/AI Contest for Crop Production Under Constraints

NATIONAL CORN GROWERS ASSOCIATION

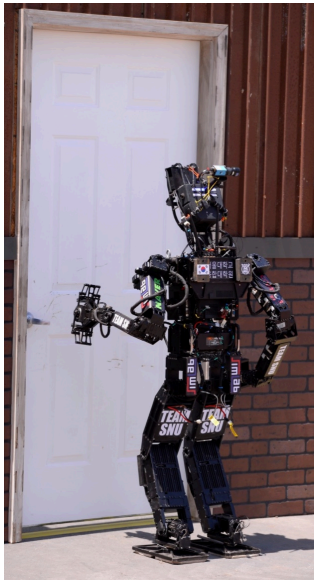
NATIONAL WINNERS FOR 2020 CORN YIELD CONTEST
CONDUCTED BY THE NATIONAL CORN GROWERS ASSOCIATION

Rank	Entrant Name	City	Field	Hybrid Brand	Number	Yield
A: Conventional Non-Irrigated						
1	Sam Santini	Stewartsville	NJ	DEKALB	DKC70-27RIB	381.5595
2	Landy Thomas	Cades	SC	Pioneer	P1847VYHR*	370.8320
3	Robert A Santini Jr	Phillipsburg	NJ	Pioneer	P1197	365.6086
B: Conventional Non-Irrigated**						
1	Kevin Kalb	Dubois	IN	DEKALB	DKC67-44RIB	385.4405
2	Rhylan Kalb	Dubois	IN	DEKALB	DKC67-44RIB	345.9045
3	Troy Uphoff	Findlay	IL	DEKALB	DKC63-57RIB	323.7983
C: No-Till Non-Irrigated						
1	Dan Gause Sr.	Scranton	SC	Pioneer	P1847VYHR*	387.0916
2	Chris Santini	Stewartsville	NJ	Pioneer	P1464AML™*	357.4564
3	Justice Family Farms	Daniels	WV	Pioneer	P1197	355.8628
I: Conventional Irrigated						
1	Don Stall	Charlotte	MI	Pioneer	P0720AM™	476.9052
2	George Andrew	Evansville	WI	Pioneer	P0720Q™	324.7783
3	Ashton Peterson	Bertrand	NE	Pioneer	P1563AML™	324.5989

Imagine …

- Create a contest for teams designing algorithms for operating the robotic pivot with a growing season long contest for crop production:
  - After planting all sensing/scouting must be carried out with the shared platform (collaboration is required)
  - Water/nutrient application post planting must use pivot platform
  - Crop protection too …
- At the beginning of the year teams write code to operate the sensors and actuators. No hands in the field. No human intervention.
- To give statistical significance to the ranking we randomize and replicate. “Teams” are the treatments.
- Apply constraints in rules. Measure runoff. Limit water.


SPECTRUM
COLLABORATION
CHALLENGE
USING AI TO UNLOCK THE TRUE POTENTIAL OF THE RF SPECTRUM

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