TRANSFORMING AGRICULTURE WITH INTELLIGENT INFRASTRUCTURE: A U.S. PERSPECTIVE

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McKnight Distinguished University Professor, Univ. of Minnesota, Minneapolis

Tuesday, Dec. 17th, 2019
Workshop on Data Science for Agriculture and Natural Resource Management
7th International Conference on Big Data Analytics

(b) Agriculture Big Data (AgBD) Challenges and Opportunities From Farm To Table: A Midwest Big Data Hub Community Whitepaper, , Ss. Shekhar et al, NSF Midwest Big Data Hub, December, 2017.

Acknowledgements: Ranbeer Chandra (Microsoft), Chandra Krintz (U.C.S.B.), Kim Van der Waal & Philip Pardey (University of Minnesota), Midwest Big Data Hub, Computing Community Consortium.
(Adapted from earlier talk in to 2018 American Association for Advancement of Sciences
Session: Transforming Cities, Transportation, and Agriculture With Intelligent Infrastructure)
AGRICULTURE & UNIV. OF MINNESOTA

• Land Grant Mission
• Contributions
  – Honeycrisp Apple: Research you can bite into
  – People: Norman Borlaug

Norman Borlaug

- Known as “The father of the Green Revolution”
- Nobel Peace Prize Winner
- University of Minnesota Graduate
- Created varieties of high yield, disease resistant wheat crops
- Result: boost the production of wheat around the world.
AGRICULTURE TODAY: SOCIETAL IMPORTANCE

• Agriculture nourishes us with
  – Food, Fiber, Fuel

• Economic Opportunities
  – 10% of U.S. Jobs
  – Helps rural America to thrive
  – Early adopter of technology, e.g., GPS, UAV, …

• Stewart of natural resources
  – Healthy private working lands
  – Conservation, Improved Watersheds, Restored Forests
AGRICULTURE TODAY: CHALLENGES

• Social-Infrastructure
  – Aging workforce, Labor shortage
  – Low urban engagement of urban

• Environmental-Infrastructure
  – Bee colony collapse
  – More intense rains & longer dry periods

• Cyber-Infrastructure Challenges
  – Broadband & cloud computing
  – Data: Yield & disease prediction
AN INTELLIGENT INFRASTRUCTURE SUCCESS STORY: PRECISION AGRICULTURE

- Transformed agriculture
  - Improves yield
  - Reduces fertilizer use & run-offs
- Intelligent Infrastructure
  - GPS, GIS, Remote Sensing, …

Yield Monitors
Direct & Remote Sensing
Precision Navigation
Variable Rate Technology

Global Positioning Systems
Geographic Information Systems

Agriculture Today
Success Stories
Transformative Opportunities
Discovery to Application
Next
Deconstructing Precision Agriculture

#AgInnovates2015

Wednesday, March 4, 2015
Reception | 5:00 to 7:00 pm
House Agriculture Committee Room, 1300 Longworth House Office Building, Washington, DC

Think Moon landing.
Think Internet.
Think iPhone and Google.
Think bigger.

Come hear U.S. farmers, leading agriculture technology companies, and scientists tell how they work together to fuel U.S. innovation and the economy to solve this global challenge.

The event will exhibit three essential technologies of precision agriculture that originated from a broad spectrum of federally funded science: Guidance Systems and GPS, Data & Mapping with GIS, and Sensors & Robotics.

Moderator
Raj Khosla, Professor of Precision Agriculture at Colorado State Univ.

Farmers
David Hula, of Renwood Farms in Jamestown, Virginia
Rod Weimer, of Fagerberg Produce in Eaton, Colorado
Del Unger, of Del Unger Farms near Carlisle, Indiana

Speakers
Mark Harrington, Vice President of Trimble
Carl J. Williams, Chief of the Quantum Measurement Division at NIST
Bill Raun, Professor at Oklahoma State Univ.
Marvin Stone, Emeritus Professor at Oklahoma State Univ.
J. Alex Thomasson, Professor at Texas A&M Univ.
Dave Gebhardt, Director of Data and Technology at Land O’Lakes, WinField
Shashi Shekhar, Professor at the Univ. of Minnesota

Hosted by the Congressional Soils Caucus
In partnership with
Agricultural Retailers Association
American Society of Plant Biologists
American Physical Society
American Society of Agronomy
Association of Equipment Manufacturers
Coalition for the Advancement of Precision Agriculture
Computing Research Association
CropLife America
Crop Science Society of America
PrecisionAg Institute
Soil Science Society of America
Task Force on American Innovation
Texas A&M AgriLife
Trimble
WinField

RSVP
http://bit.ly/1CoOYoA
AN INTELLIGENT INFRASTRUCTURE SUCCESS STORY: PRESCRIPTIVE FARMING

Monsanto, DuPont and others are pitching ‘prescriptive planting’ services to increase crops

How data-driven planting services work:
1. The farmer provides field boundaries, historic crop yields, soil conditions and other data to a company.
2. The company analyzes the data and its own information about seed performance in different areas and soil types.
3. The company sends a computer file with recommendations back to the farmer, who uploads it into a planter.
4. The farmer’s equipment then plants based upon the recommendations. The company monitors weather and other factors, advising farmers on how to manage crops as they grow.

A cornfield analysis in Iowa:
- **Red areas:** Lower number of seeds per acre recommended
- **Green areas:** Portions of the field that can grow more corn and can take more seeds per acre

Source: Monsanto
(BI-WEEKLY) CROP MONITORING & YIELD PREDICTION

Conditions:
- Exceptional
- Favourable
- Watch
- Poor
- Out-of-Season
- No Data

Countries:
- AMIS Countries
- Non-AMIS Countries

Crops:
- Maize
- Wheat
- Soybean
- Rice

AMIS
Agricultural Market Information System
GEOGGLAM
Global Agricultural Monitoring
Computing Community Consortium
Catalyst
TRANSFORMATIVE OPPORTUNITIES: SOCIAL INFRASTRUCTURE

• Challenges: Aging workforce, Labor shortage, Low urban engagement
• Intelligent Infrastructure Opportunities
  – Tele-operation
  – VR-based Training Environment

Source: L. Mathew, There is now a $300 joystick built for Farming Simulator, geek.com, 06.12.2015.
Source: Autonomous Solutions Inc. and CNH Industrial unveil concept Autonomous Tractor, Aug. 30, 2016, asirobots.com
TRANSFORMATIVE OPPORTUNITIES: ENVIRONMENTAL

- **Challenges:** Bee colony collapse, Rainfall Variability
- **Intelligent Infrastructure Opportunities**
  - Robot Bees
  - Cyber-Physical Systems for Smart Water management
    - Water sensors + data analytics + control

Source: Researchers using AI to build robotic bees, D. Harris, GigaOm, Oct 1, 2012.

ROBOTIC POLLINATORS

- Robo-Bees (Harvard U, National Science Foundation):

Source: Researchers using AI to build robotic bees, Derrick Harris, GigaOm, Oct 1, 2012.
SMART IRRIGATION: CYBER-PHYSICAL SYSTEMS

- Cyber-Physical Systems = sensors + data analytics + control

Source: This smart irrigation and water management system is controlled by your smartphone, Derek Markham, treehugger.com, July 19, 2013.
TRANSFORMATIVE OPPORTUNITIES: CYBER-INFRASTRUCTURE

- Challenges: Limited broadband, sensing, data & computing
- Intelligent Infrastructure Opportunities
  - TV Whitespace Spectrum for rural broadband
  - Geospatial Cloud & Edge Computing for farms
  - Spatial Data Science to monitor disease & predicting yield

Source: Microsoft wants to close the rural broadband gap with TV white spaces, T. Warren, theverge.com, July 11, 2017.
(WEEKLY) SWINE MONITORING & DISEASE FORECAST

• **Track** weekly infection status
  • 50% of U.S. sow population
  • PRRS & PED virus

• **Forecast virus** spread
  • from pig **movement** across farms

• **Model** regional spread
  • Identify **super-spreaders**

• **Early Warning System**
  • Altered disease dynamics Detection

• **Challenge**: Data Sharing
  • During **Epidemics** (similar to E-911)
  • Protect property rights, privacy, …

**Source**: Prof. Kim VanderWall, Univ. of Minnesota
CYBER-INFRASTRUCTURE NEEDS IN DATA-DRIVEN FARMS

- Challenges: Limited broadband, sensing, data & computing

## Intelligent Infrastructure Opportunities

- **More examples** in community whitepaper:

<table>
<thead>
<tr>
<th>Areas</th>
<th>Intelligent Infrastructure and Research Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workforce Development</td>
<td>Augmented reality; Teleoperation</td>
</tr>
<tr>
<td>Cyber Physical Systems &amp; Robotics</td>
<td>Robust high-precision positioning; Automation for labor intensive tasks</td>
</tr>
<tr>
<td>Spatiotemporal Machine Learning, Data Analytics</td>
<td>Using high resolution satellite data to monitor crops; Optimize resource allocation</td>
</tr>
<tr>
<td>Security, Privacy, Safety</td>
<td>Secure, privacy-protected farm-data sharing; Economic models to promote data sharing</td>
</tr>
<tr>
<td>Networking, Internet of Farm Things</td>
<td>Improving Broadband Network Access in Rural Farming Areas</td>
</tr>
<tr>
<td>Decision Support</td>
<td>Advanced spatiotemporal image, and video analysis techniques</td>
</tr>
<tr>
<td>Citizen Engagement</td>
<td>Social Media; Apps</td>
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**Agriculture Today** | **Success Stories** | **Transformative Opportunities** | **Discovery to Application** | **Next**

**Computing Community Consortium Catalyst**
ADVANCING SCIENCE DISCOVERY TO APPLICATION

- Knowledge **co-production** with users
  - Co-Visioning
  - Co-define Problems
  - Co-select Science Questions
  - Co-Evaluate Discoveries

- **Co-production Initiatives**
  - CRA/CCC Visioning Workshops
  - (Midwest) Big Data Hubs & Spokes
  - NSF Sustainability Research Networks
  - NSF Smart & Connected Community

- **Co-Production Examples** in my work
  - 2005: Evacuation Planning: MN local governments
  - Current: NSF SCC Project: counties, cities in MN, FL

KNOWLEDGE CO-PRODUCTION: EVACUATION PLANNING (2005)

- **Team**: US DHS, MN Dept. of Transportation, URS Corp.
  - Emergency Managers, Police, Fire Fighters, Natl. Guard
- **Co-Visioning** via monthly meetings
  - Challenges: evacuees & traffic maps
  - Police: focus on what can be done!
- **Problem Co-Definition**
  - 1-mile scenarios: 5 sites, work-day or night-time
- **Co-Discovery**
  - For 1st mile, walking faster than driving
- **Co-Evaluation**
  - Walk selected routes: avoid wooden bridge near E
  - Lock parking garages during evacuation?

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Population</th>
<th>Vehicle</th>
<th>Walking</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>143,360</td>
<td>4:45</td>
<td>1:32</td>
</tr>
<tr>
<td>B</td>
<td>83,143</td>
<td>2:45</td>
<td>1:04</td>
</tr>
<tr>
<td>C</td>
<td>27,406</td>
<td>4:27</td>
<td>1:41</td>
</tr>
<tr>
<td>D</td>
<td>50,995</td>
<td>3:41</td>
<td>1:20</td>
</tr>
<tr>
<td>E</td>
<td>3,611</td>
<td>1:21</td>
<td>0:36</td>
</tr>
</tbody>
</table>

Details: [FoxTV newsclip, Shashi Shekhar Disaster Area Evacuation Analytics](https://www.youtube.com/watch?v=PR9k72W8XK8)
KNOWLEDGE CO-PRODUCTION: NSF SMART & CONNECTED COMMUNITIES GRANT 1737633 (2017-2020)

• Team: U of Minnesota, Purdue U, FL State U, U of WA
  • Schools, Counties (e.g., Hennepin), Cities (e.g., Minneapolis, St. Paul, Tallahassee);
  • MetroLab Network, National League of Cities, ICLEI-USA, Intl. City/County

• Co-Visioning via meetings
  • Communities planning infrastructure for driver-less, post-carbon future with climate change
  • Advance Environment, Health, Wellbeing & Equity via infrastructure refinement

• Co-select Questions
  – Understand spatial equity in infrastructure & outcomes (wellbeing, health, environment)?
  – How does equity first approach differ from average-outcome based approaches?

• Problem Co-Definition: How to measure spatial equity? Well-being?

• Co-Discovery
• Co-Evaluation

• Details: University of Minnesota secures $2.5 million grant to improve quality of life in cities, October 20, 2017 (https://www.cs.umn.edu/news/filter/highlights/professor-shekhar-leads-u-m-team-granted-25-million-nsf-grant)
CONCLUSIONS & NEXT STEPS

• Agriculture is societally important and facing challenges
  – Importance: 10% of U.S. economy, …
  – Challenges: Workforce, bee colony collapse, broadband, …

• Intelligent Infrastructure has already transformed Agriculture
  – Precision Agriculture

• Many Transformative opportunities lie ahead
  – Workforce, Robo-bees, TV Whiteband, Spatial Data Science, …

• However, these will not material without
  – Federal research funding
  – Knowledge Co-production: farmers, academics, businesses, policy-makers
American AI Initiative

The American AI Initiative supporting national AI technology and innovation has spurred numerous efforts, including the NITRD National AI R&D Strategic Plan (2019 Update), the AAAI/CCC 20 year community roadmap for AI research, NIST plans for AI standards, NSF National AI Research Institutes solicitation, and related initiatives in academia, industry and government.
Figure 1. Organization of the AI R&D Strategic Plan (2019 update, to include Strategy 8). A combination of...
REFERENCES


2. S. Shekhar et al., *Agriculture Big Data (AgBD) Challenges and Opportunities From Farm To Table: A Midwest Big Data Hub Community Whitepaper*, NSF Midwest Big Data Hub, December, 2017.


