Automatic Center Pivot Speed Control for Irrigation Water Conservation

Project Update

Presented September 11, 2018
Board of Directors Meeting
High Plains Underground Water Conservation District No. 1

The Team

Dept. of Electrical and Computer Engineering, Texas A&M University
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Texas A&M AgriLife Research – Amarillo/Bushland
Thomas Marek, M.S., P.E., Senior Research Engineer
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USDA-ARS – Conservation and Production Laboratory, Bushland
Gary Marek, Ph.D., Research Agricultural Engineer

Texas A&M AgriLife Research and Extension - Lubbock
Dana Porter, Ph.D., P.E., Professor & Extension Program Leader,
Texas A&M Dept. of Biological and Agricultural Engineering

Overview, History & Context

Background & Motivation

There are some great advanced irrigation technologies (sensors, VRI, etc.) available, but they are underutilized, difficult to use, and not well integrated. Hence benefits of available technologies are not fully realized.

Approach

- Integrate in-field data (soil moisture, weather station), machine learning techniques and widely used crop models to automate irrigation scheduling
- Use off-the-shelf sensors/ components
- Design for platform independence
  - Leverage funds

Objective(s)

Overall Objective: Increase realized benefits of irrigation technologies through integrating and automating information and decision support tools.

Specific Objectives:
- Sensor network with anomaly detection
- Controller using real-time & forecast data; integration of data, models, safety
- User-friendly interface

Outcomes

- Intellectual property (patents pending)
- Presentations at IEEE, IA, and ASABE meetings; field days at Bushland, TX and Garden City, KS
- 2 PhD students + 1 recent graduate!
- Significant improvements over existing commercially available systems

Outcomes: The Team

2 PhD students have made major contributions to this work:

Lijia (Justin) Sun, PhD, TAMU Electrical and Computer Engineering

Yanxiang Yang, PhD candidate, TAMU Electrical and Computer Engineering

New addition to our team:
Hongxin Kong, PhD student, TAMU Electrical and Computer Engineering

Special thanks to Kevin Heflin and Gary Marek for their assistance.

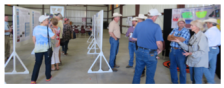
Outcomes: Field Days for Stakeholders

40 Year Celebration of Center Pivot Irrigation and Summer Crops Field Day, Bushland, TX, August 9, 2018.

Thomas Marek and Kevin Heflin presented the developments at this project. We received very favorable feedback.

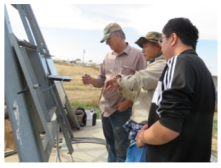
Technology Farm Field Day, Garden City, KS, August 15, 2018.

Dana Porter presented our activities and discussed safety precautions needed for center pivot irrigation systems.



Outcomes: Significant improvements over commercially available systems

- Improved center pivot irrigation positioning and speed control
- Improved variable rate irrigation (VRI) prescriptions: real-time updates using in-field near real time data and predictive capabilities.
- Soil moisture sensor placement method to optimize wireless sensor nodes to balance cost and data reliability
- Simplified integration of information for irrigation decisions using commercially available components, greatly improving the potential benefit of existing technologies for a relatively low cost.



Goal

- Increase realized benefits of irrigation technologies.

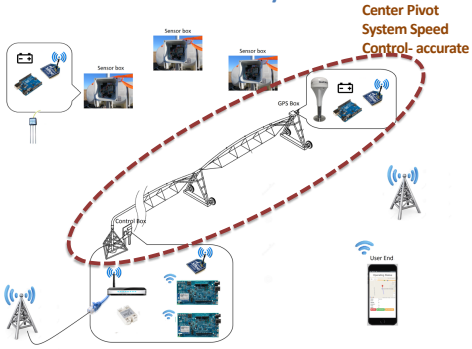
Objectives

- Wireless sensor network with anomaly detection
- Irrigation system controller using real-time & forecast data; integration of data & models; safety
- User-friendly interface

Approach

- Integrate in-field data, using machine learning techniques and crop models to automate irrigation scheduling
- Use off-the-shelf sensors / components
- Design for platform independence
- Cost-effective

Overview of the System



Results

We developed a technology suite that addresses:

- **Precise center pivot system speed control**
- **Methodology for optimizing number and placement of soil moisture sensors**
- **Irrigation system control with predictive water balance capabilities**

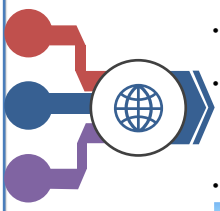
Results

Reliable Sensing Methodology

Statistically Inferring Soil Moisture Levels
Given limited data, using statistical method to infer the soil moisture level at any place in the field

Detecting Sensor Faults
Using proposed fault detection algorithm to detect sensor faults

Smart Sensor Placement
Using less sensor to gain best estimation . Sensing result is still acceptable despite few sensor failures.



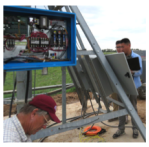
- **Greatly extend system lifetime**
- **Make sensing data more trustable and reliable**
- **Lower the cost**

Results

- Real-time soil moisture monitoring
- Near real-time and short-term predictive crop evapotranspiration
- Quantitative precipitation forecasting
- Management allowable depletion
- Artificial Intelligence Algorithm

Irrigation Decision Process (can be over-ridden manually by the user)

Automate the "when, where and how much" decision



Results

Center pivot irrigation speed control is fundamental to controlling irrigation application depth, and accurate speed control is the basis of the most commonly used Variable Rate Irrigation applications.

Improved speed control

- **overcomes the accuracy limitations of mechanical slippage;**
- **wirelessly integrates location; and**
- **is independent of the irrigation system manufacturer's control platform.**

Outcomes: Improvements over commercially available systems

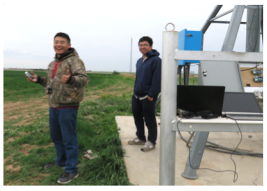
Patents Pending

- Improved center pivot irrigation positioning and speed control
- Improved variable rate irrigation (VRI) prescriptions: real-time updates using in-field near real-time data and near-term predictive capabilities
- Soil moisture sensor placement method to optimize wireless sensor nodes for balance of cost and data reliability
- Simplified integration of information for irrigation decisions using commercially available components, greatly improving the potential benefit of existing technologies for a relatively low cost

Acknowledgements and Considerations

Funding and in-kind support provided by the **Texas A&M University System Water Seed Grant: Creation and Deployment of Water-Use Efficient Technology Platforms Program,** Texas A&M AgriLife Research, the Texas A&M AgriLife Extension Service and the Texas A&M Engineering Experiment Station (TEES)**; High Plains Underground Water Conservation District** Number 1; and the **USDA-ARS Ogallala Aquifer Program**.

The **Ogallala Aquifer Program (OAP)** is a consortium of the USDA Agricultural Research Service, Kansas State University, Texas A&M University, Texas Tech University and West Texas A&M University. Associated projects are included in the USDA REEport system that supports state and federal Hatch projects.



Thank you.

Research Report
High Plains Underground Water Conservation District Number 1

Automatic Center Pivot Speed Control for Irrigation Water Conservation

Dana Porter, Jiang Hu, Thomas Marek,
Justin Sun, Yanxiang Yang and Kevin Heflin

Executive Summary

Advances in irrigation technologies continue to improve the potential precision and efficiency with which irrigation water can be applied. Agricultural research continues to increase the knowledge base from which efficient strategies and recommendations emerge. Internet of Things, sensors, advances in wireless communications capabilities and advances in Variable Rate Irrigation further increase the information available to improve irrigation management, matching irrigation application to crop water demands. Yet most potential benefits of these technologies are not fully realized. More information and more complex systems do not necessarily translate into water savings or improved crop yields. Our team is developing integration tools to take advantage of the new technology components and research-based recommendations to help end-users take better advantage of the technologies and information available. This project is focusing on improving a critical part of an overall suite of technologies. By improving center pivot system positioning and speed control, we aim to improve feasibility and potential benefits realized from Variable Rate Irrigation, split pivot crop management strategies, and other precision irrigation applications.

Background

Agricultural irrigation accounts for 90% of the total water demand in the Texas High Plains. Site-Specific Variable Rate Irrigation (SS-VRI) technologies are used to varying degrees in research applications. Variable Rate Irrigation (VRI) features also are available on many commercial center pivot irrigation systems. However, adoption of VRI is low, and few end-users are able to fully realize the potential benefits. Several factors limiting full applications of VRI include lack of technical support, difficulty of use, expertise and time required to generate and update prescriptions, and associated costs for more advanced hardware and technical services. The research team has developed an integrated center pivot irrigation technology suite that includes a network of wireless soil moisture sensors with communication of real-time field based data to the controller; integration of near real-time and short term forecast weather data to inform an imbedded crop water use model; and irrigation controller package (hardware and software) to automate decisions, “when, where and how much” irrigation to apply, within practical constraints of the system.

An essential element of this overall technology suite is precise control of the position and speed of the center pivot irrigation system to ensure the desired amount of water is applied precisely in the field where it is intended. Commercially available center pivot systems with mechanical speed/position control tend to “drift” from calibration; a few degrees of error can result in over-shooting or under-shooting the target. Speed may

also vary due to mechanical (tower wheel) slippage, resulting in faster or slower movement of the system, and hence lower or greater irrigation water application depths. In this project we have made improvements to the center pivot speed / position control. We are working to further improve the precision, while maintaining the relatively low cost.

Objectives and Expected Impact

The objective of this project is to demonstrate an advanced user-friendly center pivot speed control system, including automated control software, that can potentially reduce water use without significant yield/quality loss. The result is a controller that is relatively simple to use, uses low cost modern “off the shelf” electronic hardware components, and offers a significantly greater degree of control flexibility in its application than is available commercially.

While full application of VRI may not be economically justified in most applications, aspects of VRI can be quite helpful in instances as simple as managing irrigation in “split pivot” applications, wherein a field may be planted with multiple crops or on multiple planting dates to better accommodate peak crop water requirements with limited well capacities. VRI should make better sense for these flexible irrigation approaches if its application is simplified; if the cost is reasonable; and if the precision of the speed and positioning control of the pivot is adequate.

Approach

An important emphasis of this project is to make the system easy to use and flexible (modular), allowing end-users to adopt the level of automation (fully manual to fully automated), according to their preferences and needs. The basic control configuration is one of a micro-controller that can turn on/off the center pivot motor; by changing the on/off time ratio (percent engagement ratio), the center pivot motion speed is controlled, and hence the water application depth is controlled. An advanced feature of this system is that the cycle period can be adjusted as easily as the percent engagement ratio. This feature allows for flexible and precise irrigation application depths. The control system offers two options that can help to improve water use efficiency. The modular controller design allows users to activate either one or both of 1) a wireless field sensor network that can communicate with the controller at the center pivot point and inform the “whether and how much to irrigate” decision; and 2) software that links the soil moisture sensor data into the center pivot speed control system such that the control is automated and maintained according to sensor data inputs. Manual interruption and override features allow the user ultimate control of the system. Like some commercially available advanced irrigation controller products, IoT capabilities allow end-users to remotely monitor the status of soil moisture, weather data and the irrigation system status. This new system expands upon these functionalities, incorporating potential use of weather forecast information automatically and programming the system via an advanced control algorithm. The algorithm decides to whether to activate the pivot (and well) system and control the center pivot speed according to current or anticipated weather conditions and current and anticipated crop water requirements. It

automatically translates the amount of irrigation water needed into the desired center pivot speed.

Figure 1. Thomas Marek is describing advanced irrigation technologies at the center pivot irrigation system at Texas A&M AgriLife Field Day, Bushland. This is the irrigation system where we are testing the advanced automated speed control.

The controller includes multiple safety features. For example, it can restrict the movement of center pivot system within a specified region, which is based on the end tower location of the center pivot system and is obtained by GPS (not by resolver means- which are relatively inaccurate), which then is communicated to the microcontroller at the pivot point.

Key components of this system were previously developed through a project sponsored by Texas A&M AgriLife Research and Texas A&M Engineering Experiment Station. These include the wireless sensor network, the microcontroller configuration and processing at the pivot point that controls the pivot speed, and the communication linkages between the controller interface application with smart phones. Some of these components and activities are illustrated in Figures 2-5. Software simulations using corn as the target crop indicate that as much as a 20% water use reduction can be achieved without significantly affecting yield. Thus, the system promises to support better overall water use efficiency and production management.

Figure 2. Installing soil moisture sensors in the field at Bushland.

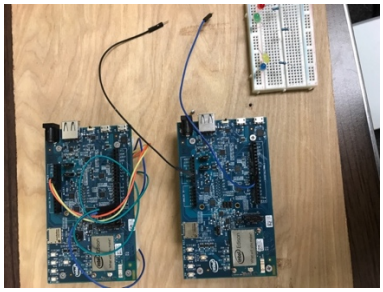


Figure 3. Microcontroller boards used in data acquisition, data processing and irrigation system control.

Figure 4. Yanxiang Yang and Justin Sun installing positioning equipment on the center pivot system.

Figure 5. Smart phone app provides the end-user with access to operational status and control, as well as field conditions.

Since key system components have been developed and initially tested, this project focuses on system integration and overall evaluation of system performance in the field.

Successes and Setbacks

We have been able to make improvements in the center pivot irrigation system position and control system by using commercially available global positioning system (GPS) technology. Commercially available center pivot systems can easily “drift” 2-3 degrees – or more – per rotation; this can result in an error in positioning up to 45 ft. or even 67 ft. at the outside tower of a quarter mile (radius) field. While we continue to work toward improving this performance, we are able to bring that error to under 15 ft. We hope to get this consistently below a few ft. of error, while maintaining the low cost.

While we had a delay in getting the contract finalized due to miscommunications among our university’s Sponsored Research Services (grants and contracts) office (creating some challenges in paying graduate students), we were able to begin the work on time.

While we appreciate and respect the need for security of data and computer networks, we encountered some substantial delays in achieving full WiFi access to our remote site, as our project was pushing the proverbial envelope regarding experience of our internal agency “IT” officials. Dr. Heflin (Assistant Research Scientist, AgriLife – Bushland) was diligent in communicating with headquarters IT leaders to resolve the accessibility issues, and Justin Sun and Yanxiang Yang were able to address potential security issues by developing appropriate password protections to our user interface and other necessary safeguards to prevent data breaches and other potential interference from non-authorized users. While we were waiting for the issue to be resolved, we used a portable “WiFi trailer” and computer smart phone hotspots. We were absolutely committed to achieving the connectivity we needed within the policy restrictions of our agency. This experience has made us more sensitive to a real limitation of internet connectivity and accessibility which can limit successful applications of many Internet of Things (IoT) and big data applications in rural areas.

Like many commercial farming operations in the region, we deal with irrigation water capacity limitations at our research farms. The irrigation water supply at the Bushland facility is a shared resource, so we were not able to test the controller in “full automatic” mode all season. We had to constrain our applications to the periods when water was available to our project group. We can continue to improve and test the positioning and speed control equipment and algorithms even without water application.

Portions of this work have been presented in a presentation, “Integration of Data and Advanced Technologies to Improve Center Pivot Irrigation Management,” at the 2018 Annual International Meeting of the American Society of Agricultural and Biological Engineers, Detroit, MI, August 1, 2018 and at the “Celebrating 40 Years of Center Pivot Irrigation Field Day” at Bushland, TX, August 9, 2018. Both presentations generated interest – and numerous questions – from the audiences.

Expected Outcomes and Water Conservation

We have limited field data to date to assess ultimate water savings from application of this technology. Crop simulations using widely used models (including DSSAT) indicate that as much as a 20% water use reduction (compared to full crop evapotranspiration demand) can be achieved without significantly affecting corn yield. This is consistent with other research conducted in other studies in the region. This advanced controller uses integrated in-field, near real-time and predictive data; water balance and crop water use models; and improved precision in irrigation system positioning, speed and water application depths to simplify the irrigation decision making, improving adoption of scientific irrigation scheduling. Hence, we hope that the overall system will make it easier for agricultural producers to have the information they need to maintain crop productivity with a managed reduced irrigation strategy. The automated center pivot speed control addressed in this project is an important component of the technology suite.

Budget and Expenditures

Total budget request: $29,000.

- *Salary for one graduate research assistant (9 months): $14,400*
  Graduate student assistantships for Justin Sun and Yanxiang Yang, PhD students, Department of Electrical and Computer Engineering, Texas A&M University
- *Tuition and fees for one graduate research assistant (9 months): $6,600*
  Tuition and fees for Justin Sun and Yanxiang Yang is $7,431.58 to date.
- *Travel from Texas A&M University College Station campus to the experiment field at Bushland: $6,000*
  So far, we have spent $1,577 for travel for Sun and Yang to travel to Bushland. We used other sources for Porter and Marek to travel to College Station to meet with them on campus, since we often meet with the students when we travel there for other meetings. We also visit via Web Conference on a bi-weekly schedule, as this is a cost-effective means of coordinating activities.
- *Parts (cable, connectors, PCB boards, etc.): $2,000*
  So far, $423.28 has been spent on cables, PCB boards, connectors, etc. Other hardware, software and other expenses have been leveraged from other sources. (Preliminary research on this project was funded by Texas A&M AgriLife Research and Extension Service and Texas A&M Engineering Experiment Station from September 1, 2015 to August 31, 2017.)