SPIDER SENSORS

EASY AND AFFORDABLE WATER SENSOR SYSTEMS

Nathaniel Haut | Matthew Schafer | William Hackbarth

Abstract

The Spider Sensor System utilizes water sensor technology, in concurrence with Raspberry Pi and heat map programming, to provide an affordable and cohesive method to optimize irrigation techniques.

The Spider Sensor System sends periodic heat maps to farmers, notifying them which points of their farm need to be watered at specific times. The green represents places where the volumetric water content is within acceptable levels; the blue is oversaturated soil and the red are places that need to be watered.

By notifying farmers of exactly when specific parts of their field need to watered, they can save millions of gallons of water, and millions of dollars per year.

The decreased water usage on farms would increase the global water supply and decrease water-deficiency situations. Another result of Spider Sensors would be an increased food supplies and cheaper produce, serving to decrease poverty and hunger, potentially on a global scale.

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Key Words

- **Volumetric Water Content –** percentage of soil composition that is water
- **Raspberry Pi-** basic computer used to collect and process data
- **Irrigation techniques** – methods for saving water on farms
- **Heat map -** reference for farmers to understand how to improve irrigation techniques
- **Spider Sensors-** our sensor system, used to optimize irrigation to save water
  Water Sensors- used to monitor volumetric water content

Acknowledgments

We would like to thank Bob Fox, our computer science teacher, coach and mentor, for guiding us throughout the experiment and providing us with the resources required to gather our data and reach our conclusions. He has helped us over the course of seven months, allowing us to reach our full potential with this project.

We would also like to thank the scientists we spoke to at the Michigan State University College of Agriculture and Biosystems Engineering, who allowed us to visit their college and provided us with vital knowledge on irrigation techniques and water sensors. Dr. Steve Safferman, along with Specialist Steve Miller and Research Assistant Steve Marquie, gave us a tour of their labs and a history of efforts in sensor-based farming, along with scientific knowledge that was incredibly helpful when creating our experiment and sensor system.

In addition, we thank Dr. Darrell Donahue, the Chair of Biosystems and Agricultural Engineering at Michigan State University for taking us out to lunch and taking special interest in our project. He also provided us with great insight into the agricultural specifics and potential problems regarding our project.

Lastly, we are greatly appreciative of the A.H. Nickless Inovation Award Competition, and the people who run this tremendous program every year, for providing the spark for us to create this project and allowing us to present the idea to seven well-established scientists.

Biography

Nathan Haut

I am interested in computer science and chemistry. I am a baseball and tennis player at my high school. I am planning on getting a career in cheminformatics, which is a combination of computer science and chemistry.

Will Hackbarth

My passions are writing, journalism, and teaching. At my high school, I am the Editor-inChief of the newspaper and work at a local daycare. In the future, I plan to get a degree in teaching, and combine my love of writing with that of working with children.

Matthew Schafer

I have strong interests in computer science, which I plan to study in college at Michigan State University. I participate in my high school's programming club and learn how to code Raspberry Pi's in my free time.

Introduction

In modern agriculture, current techniques of irrigation based on uniform, generalized schedules, fall far short of optimization. According to the Food and Agricultural Organization of the United Nations, many countries are currently in a water-deficit situation[ii]. They are removing water faster than it can be replenished, and, in most cases, are using much more water than necessary. As we learned from speaking to scientists at Michigan State University's College of Biosystems and Agricultural Engineering, time-based irrigation schedules often result in some portions of the farm lacking water, while others suffer from oversaturation. Many companies and colleges, including Michigan State, have attempted to use water sensors to fix this problem. The use of sensors would allow farmers to identify water saturation discrepancies in different parts of their field, and then use the sensor data to customize the amount of water used and the frequency of irrigation, to result in maximum growth and minimal water usage[ix].

However, according to our sources at Michigan State, there are two major complications preventing the widespread implementation of sensor-based farming: the lack of a clear data-interpretation method and cost[ix]. Our innovation, the Spider Sensor System, integrates heat map technology to provide a comprehensive visual of farms' volumetric water content, and provides a cost-effective method of sensor integration. With Spider Sensors, farmers could optimize their irrigation methods, and the average farm in America could save over 80 million gallons of water, as well as more than 2 million dollars, per year.

Executive Summary

How Spider Sensors Work

The Spider Sensor System uses water sensors to monitor the volumetric water content of farm soil. The sensors relay the information to a Raspberry Pi, which cross-references the volumetric water content at each sensor location to the preferred amount, set by the farmer, usually between 15 to 20% volumetric water content[ix]. These values are represented in a heat map that provides a comprehensive visual of an entire field. Any location under the recommended amount is shown to be red, any crops within acceptable levels as green, and oversaturated areas as blue. This will allow farmers to see which specific parts of their farm need more watering, which need less, and adjust accordingly.

External Factors

There are currently several farmers, colleges, and businesses around the United States investing in water sensors, but they are all encountering the same problems. There is no clear way to interpret the data, and it is challenging to justify the cost of filling an entire farm field with sensors. The Spider Sensor System addresses these problems and provides viable solutions.

Aspects of Innovation

The Spider Sensor System builds upon current sensor technology, integrating the use of a heat map to provide a clear, simple method for farmers to interpret the sensor data. With the use of several sensors connected to one Raspberry Pi, repeated throughout an entire field, farmers could save large amounts of water and reduce cost significantly. With an easy way to interpret the sensor data and an affordable method of implementation, Spider Sensors provides the first viable system of soil sensors.

Worldwide Benefits

The United Nations Food and Agriculture Organization estimates that 69% of global water withdrawals are used for agriculture[viii]. Because farming is the leading cause of water consumption, any reduction in the amount used for irrigation would increase the global water supply and allow more people to receive clean drinking water. Widespread integration of Spider Sensor Systems would significantly reduce water usage, through providing farmers with the means to optimize their irrigation schedules. Reduced water usage would decrease the amount of fertilizer runoff, resulting in a healthier environment.

The savings in water would also give farmers the ability to produce crops at a lower cost. As a result, the cost of food would decrease, while the supply would increase, reducing hunger for impoverished families. Families and farms alike would have more money to spend, contributing to an economic boost.

Materials and Methods

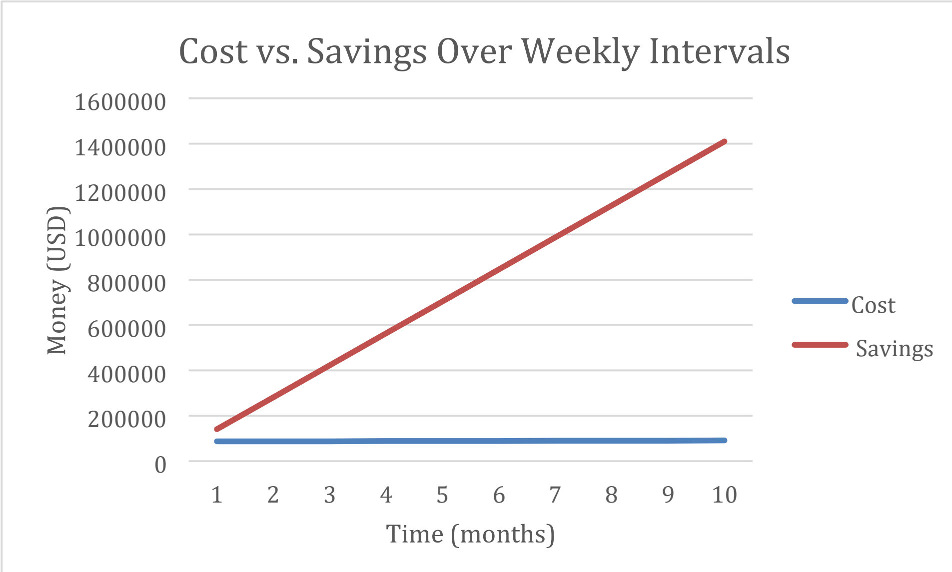
Our team set out to prove the use of water sensors could increase irrigation efficiency and reduce costs by testing them in an experiment that emulated a soybean farm. From our experiment, we were able to calculate the amount of water and money that farmers would be able to save through the use of our product.

The Experiment

In order to prove our product would maintain plant growth and reduce cost, we planted two rows of soybeans. We initially watered the plants periodically, in accordance with a normal irrigation schedule. Then, we placed moisture sensors into the soil, connected them to a Raspberry Pi, and had them monitor the volumetric water content of at each soybean plant. We created several soil samples that we manually saturated – one at 15, 20, 25 and 30 % saturation – in order to find the degree of adjustment from the values the sensors were giving us. After the sensors provided us with usable values, we sent this data to a heat map, which color-coded our entire plot of soybeans – red for a lack of water, green for the crops within recommended levels, and blue for oversaturation. This heat map notified us when each soybean needed watering. The use of the heat map in tandem with the water sensors allowed us to only water the soybeans when needed, instead of on a regular, standardized schedule.

Results

By only watering the plants when they were under 15% volumetric water content, we were able to save 1,346 ml of water over five days, or 269.5 ml per day. Over the entirety of our test plot, which was 36 X 8 inches, there was .936 ml of water saved per square inch, per day. When scaled up, there is a total of 5,869,710 ml (5,869.71 L) of water saved per acre, per day. This is equivalent to 1,550.61 gallons of water saved per acre, per day. When we extended these savings over the course of a Michigan growing season, 120 days[v], we found that farmers would save 186,000 gallons per year, per acre. According to the United States Department of Agriculture, the average size of all 2.1 million American farms is 434 acres[iii]. Therefore, an average sized farm in America would save 80,724,000 gallons of water per year. The largest farms average around 3,300 acres, of which about 1,020 are irrigated, according to the 2008 census[viii]. These farms would save 189,720,000 gallons of water per year. Based on the recommended quantity of irrigation for maximum soybean growth, an acre of crops would require 954.45 gallons of water per day. Because we know that the average cost of irrigation on medium-size fields is about $30 per acre, according the United States Department of Agriculture, the cost of water is about $.031 per gallon[viii]. When factoring in this cost, farmers of averagesized farms would save around $2,537,293.73 per year. To implement a Spider Sensor System, farmers would need 4,356 water sensors, which would cost $29,403. If farmers opted for case-protected water sensors, their cost would increase to $70,959.24. In addition, they would need 436 Raspberry Pis – one for every ten sensors – which would cost $52,280.76. Accounting for an approximate of $5000 in wire costs, and a maximum of $2000 in installation fees, the total price of Spider Sensors would be a minimum of $88,683.76, and a maximum of around $130,240.00 – well below the amount saved within one year of their use. Assuming that a tenth of the sensors and Raspberry Pis would need to be replaced each year, the annual cost of upkeep would be $8,168.38. Since farmers would be saving at least 2 million dollars in water each year, this system would be extremely profitable.



Market Study and Demand

In speaking with Darrell Donahue, the Chair of Biosystems and Agricultural Engineering at Michigan State University, as well as three other researchers – Steve Safferman, Steve Marquie, and Steve Miller – we gathered that there has been a push for water sensors over the past few years, but there are several problems that prevent their widespread implementation[ix]. In their own experience with soil sensors, they found the data they received to be difficult to interpret, and the cost of the sensors' integration and upkeep extremely costly. They had met some farmers, particularly quite successful and wealthy ones, who used sensors in some parts of their farms. However, these farmers only used the sensors in specific areas, for an additional reference point. There was a lack of any widespread sensor use over entire farms.

Spider Sensors would allow farmers to cover much of their farm with water sensors, by providing a cost-effective fiscal strategy and a comprehensive method of interpreting data, through the use of Raspberry Pis and heat maps. Because Spider Sensors would provide an easy method for farmers reduce their use of water, while increasing the health of their crops, there would be a significant demand for our product.

Research and Discussion of Existing Technology

Potential Competitors

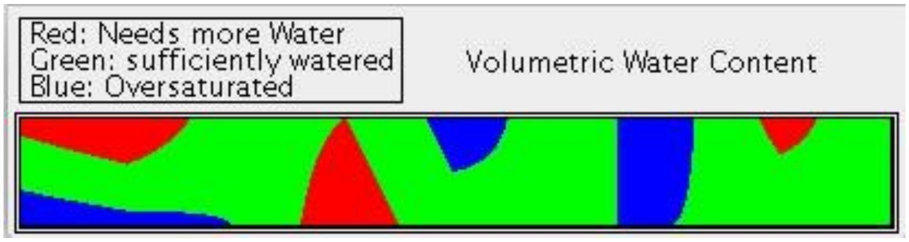
There are many universities currently experimenting with a similar implementation of water sensors, including Colorado State, Cornell, Georgia, Maryland, and Michigan State[vii]. However, their involvement with sensor-based farming is primarily done for research purposes.

Through our research, we identified two prominent businesses providing services similar to ours in the private sector: FarmSolutions and FarmConnect. FarmConnect uses Rubicon's field software, in conjunction with communication technology, to allow farmers to monitor irrigation online. Their product records data every fifteen minutes, graphs it, and delivers it to farmers via email and/or SMS alerts[vi].

FarmSolutions also provides irrigation monitoring services, using graphs gathered from sensor data. This service is slightly more impressive than Rubicon's Farm Solutions, as it combines many different visuals and the use of drones to create an aerial view of fields. In addition, they provide a more extensive mobile app with scheduling and image analysis options[i].

	Integrated Sensor Technology	Data Analysis Options	Clear, concise data and heat map imagery	Cost effective fiscal plan
FarmSolutions	✓	✓	✗	✗
FarmConnect	✓	✓	✗	✗
SpiderSensors	✓	✓	✓	✓

Innovation on Existing Technology



An example of the heat mapping technology sets Spider Sensors apart from its competitors.

Our project improves upon existing sensor systems by providing more comprehensive visuals and simpler implementation. Ease of use and simple interpretation are two important qualities when trying to appeal to massive amounts of people, and our product provides that in a way that no one else has. Instead of taking data at periodic intervals and displaying it in complicated, extensive graphs, we have coded a program that displays the saturation of soil in an easy-to-read heat map. The current sensor technologies give farmers an excess of data, complicating the process to the extent that it is unnecessarily challenging to determine which plants need watering. This is especially important when the average farmer spends around 5% of their day on irrigation decisions, according to an interview in the farming newsletter GreenBiz[iv]. With our heat map, farmers can quickly see which parts of their farms need more water, and which parts of their crops are oversaturated. In addition, Spider Sensors only sends this data when there is a potential problem, so farmers will not have to sift through hours upon hours of data, recorded in fifteen-minute intervals, to discover problems with their irrigation schedules. Instead of an all-inclusive, intricate overhaul of traditional farming, we provide an easy, clear reference point for farmers to use in addition to their preexisting agricultural knowledge.

Financial Plan

Moving Forward

In the future, there are two directions we could take our innovation. We could continue the development of our own sensor systems and mapping technology, and eventually release it on the market in the form of a mobile application or computer program. Due to the calculated cost of implementing a Spider Sensor System, as demonstrated in the Results section, we would have to charge the average farm $100,000.00 for a regular installation, and $150,000.00 for a weather-proof sensor installation, in order to make a profit. Although this price tag sounds expensive, the amount of water and money saved through the use of our system would interest many farmers. Before installing our system, we would offer a sample installation over a small portion of their field, which we would pay for out of pocket, and eventually through company funds. This would only cost between $1500 and $2000, so it would be affordable for us. If the farmer is satisfied with our sample demonstration, and wants to implement the sensors over their entire field, they would pay the money in advance, or through monthly payments spread over a set amount of years. If we took this route, we would be starting our own business, and therefore would not be reliant on any further grants or partnerships.

Alternatively, we are considering partnering with an existing water sensor company, in order to integrate our heat mapping technology and sensor-network structure with their existing technology and resources. Together, we would create an affordable, streamlined sensor system, along with an application that would utilize our heat map to provide a simple way to see the volumetric water content of farm fields as a whole. With the use of this application, farmers could quickly tell how they need to alter their irrigation scheduling in order to ensure each plant is getting the optimal level of watering. This option would reduce our personal cost, as we would not have to purchase the hardware ourselves. Instead, we could work with an existing company, such as FarmSolutions or FarmConnect, to integrate our mapping technology and sensor-network structure with their existing services. If we received 20% of each transaction, based on the aforementioned projected cost of installation, we would receive $20,000 - $30,000 per transaction on an average farm.

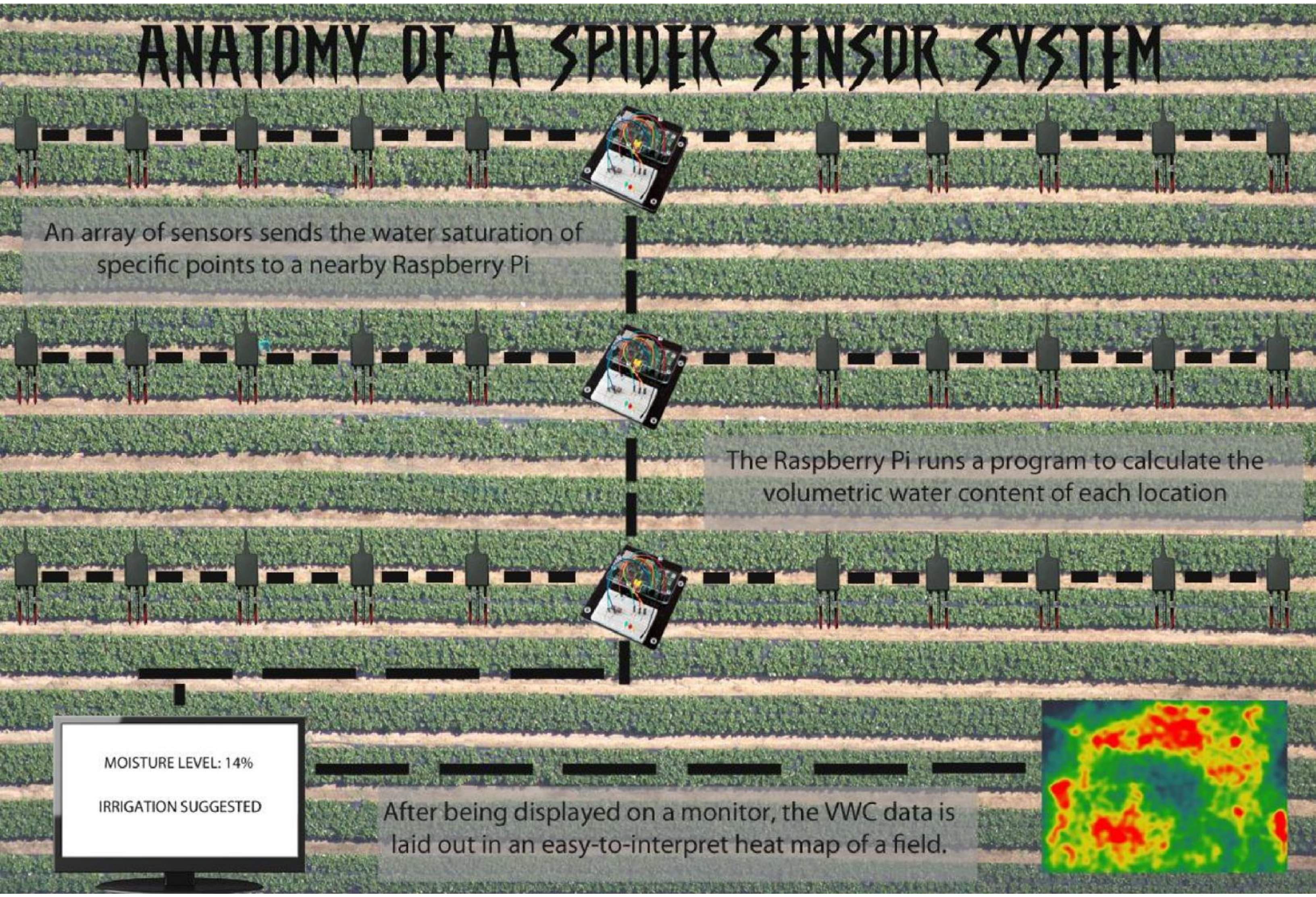
Costs for Research and Development

Cost	Purchased product
$29.96	Growing supplies (soil, planters, seeds)
$27.00 $239.82	Moisture sensors Raspberry Pi + electronics
$54.63	Grow Bulbs
$31.74	Grow Light Fixtures
$25.00	Presentation Supplies
$100.00	Team shirts
$75.00	Presentation poster
Total	**$582.45**

Timeline

Date	Tasks
October 12	Formulate idea to improve irrigation using water sensors
October 15-31	Created the Phase One Report Final Draft
November 16 – December 14	Contact Michigan State University for assistance, research and purchase required materials
December 18 – February 17th	Construction and optimization of the Raspberry Pi computer
February 25	Electronic conference with MSU researchers and professors for advice on our experiment
February 26	Plant Soybean plants
March 3	Visit MSU College of Biosystems and Agricultural Engineering to speak to our contacts
March 4	Begin coding a heat mapping program in Java
March 8	Begin coding a program for the Raspberry Pi to calculate volumetric water content of soil samples
March 16	Heat map technology completed
March 18	Successful trial of using Raspberry pi and water sensors to report volumetric water content of a soil sample
March 18 - 20	Test soil samples of 15, 20, 25, and 35 percent water saturation, to create a baseline for our experiment and test the accuracy of the sensor readings.
March 19 - 31	Complete the Phase Two Final Project Paper

Graphical Representation



Conclusions

#1: Current irrigation methods are far from optimization.

#2: The use of sensors to monitor soil saturation allows farmers to save water. **#3:** The savings in water spending greatly exceed the expenses of integrating such a system.

#4: The heat map technology provides a clear, concise, comprehensive visual for farmers to understand how their farm is being irrigated and what needs to change to save water.

#5: The water saved through using sensor-based farming can be used to increase the global water supply and decrease the cost of food worldwide.

#6: By reducing the amount of water used on fields, there would be less fertilizer runoff in local tributaries, improving the environment and reducing the amount of fertilizer used by farmers.

#7: Spider Sensors' heat mapping technology and cost-effective plan renders the system more effective at saving water than all existing sensor systems.

Closing Statement

In recent years, there have been many efforts to integrate water sensors with traditional farmers, to further optimize agricultural irrigation. It is clear that the sensor-based farming is the way of the future. However, there is no current provider of a simple, easy alert system; only systems that relay vast amounts of data and overlay them into extensive, intricate graphs. By combining existing sensor technology with a comprehensive heat map, Spider Sensors provides a simple and affordable method for farmers to integrate sensor technology and optimize their irrigation schedules.

Sources

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[ix] Interviewees

Darrell Donahue; Doctor; Chair of Biosystems and Agricultural Engineering; Michigan State University

Steve Safferman; Associate Professor; Michigan State University

Steve Marquie; Research Assistant I; Michigan State University

Steve Miller; Specialist; Michigan State University