Automated Crop Irrigation and Monitoring

AquaByte

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Abstract

On the Field and Fork Farm, crops are irrigated through a series of timers that periodically send water to different fields for various set times. This system works well, however, it is not very responsive to changes such as heavy rain, leaks, or other changes that would need to adjust the watering schedule. Since it follows a set schedule, it can be an inefficient usage of water since it cannot determine when it is best to water, but rather constantly waters to make sure plants have the water they need. It also must be managed on site, so someone must be on the farm physically to change the watering schedule or notice leaks. This project aims to develop an automated irrigation system that leverages different sensors, including soil moisture and sunlight intensity sensors, that are periodically measured by a microcontroller and sent wirelessly to an online dashboard. These live readings and values will be used to dynamically determine when plants need watering to conserve water and remove the need for a person to manage it day to day. The online dashboard will allow a user to view the data collected from each microcontroller and remotely manage the irrigation to turn it on or off. While other solutions exist for this issue, our goal is to use cheaply available microcontrollers and sensors to keep costs low for the Field and Fork Farm. Overall, this automated irrigation controller simplifies farm management by reducing the daily workload required for irrigation, allowing farmers to focus on other essential tasks.

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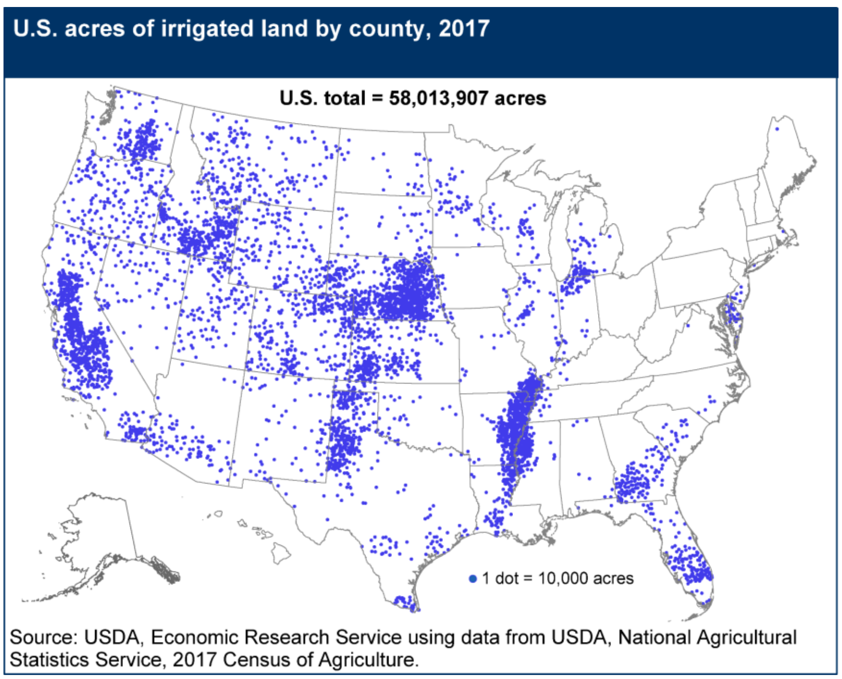
Introduction and Motivation

Water management in agriculture is a significant challenge, with inefficient irrigation methods leading to water waste, increased costs, or inconsistent crop yields. Farmers must manually monitor weather and adjust irrigation schedules, which is time-consuming and prone to human error. Additionally, climate variability makes it difficult to predict the optimal watering times. In the United States, agricultural irrigation accounted for 42% of the nation's total freshwater usage in 2015 (Dieter et al., 2018). As agricultural irrigation is a significant usage of water, in places where water is scarce, such as California, or places where the soil is more sandy and does not hold onto water, such as Florida, it is imperative that water is managed carefully.



To help manage water usage on irrigated agricultural land, our project proposes creating smart systems that optimize water usage by leveraging technology such as soil moisture sensors, weather data, and automated valves to ensure crops receive the right amount of water at the right time. This not only conserves water but also reduces labor costs and improves crop health. With many low cost sensors and microcontrollers readily available in the market, creating a scalable and affordable system is very feasible.

Our project focuses on the Field and Fork Farm at the University of Florida, which currently uses traditional irrigation systems which utilize timers to control watering schedules. We propose an intelligent, sensor-based irrigation system that automatically adjusts water distribution based on real-time environmental conditions. This will be accomplished by utilizing moisture, light, and temperature sensors to monitor the environment, and a microcontroller to utilize this data and control irrigation via solenoids. This microcontroller will communicate with an online dashboard as well for ease of access to control irrigation and monitor data. The impact of this project will be in water conservation, simplified farm management, and improving watering consistency leading to better crop yield. By streamlining irrigation management, a farmer’s time and energy can go into other aspects of the farm.

Literature Survey

Literature Survey 1:

The first piece of research we found discusses the importance of soil moisture on irrigation and the yield of crops, and how soil moisture sensor technology can help agricultural performance (Limin Yu, et al.). The researchers discuss how they analyzed and compared different measurement methods and how these sensors can be improved for future development. They were able to test different kinds of moisture sensors and report the main advantages and takeaways of how each one performed. During their testing, they determined that different environmental factors, such as temperature, affected the measurements of the soil moisture sensors, which is similar to what we will be testing and measuring. While our project will be on a much smaller scale, it can also be used to determine more about the improvement of soil moisture sensors and how they can be used in larger scale applications.

Literature Survey 2:

This idea was also carried out on farms in Indonesia by some researchers from the Institute of Informatics and Computing Energy at Universiti Tenaga Nasional, the University Hassan II of Casablanca, and the Department of Electrical Engineering at Gujarat Technological University (Ipin Prasojo, et al.). They aimed to improve the efficiency of the farms because the farmers didn’t often grow anything in dry seasons due to concerns about watering issues. In their research, they designed a microcontroller chip that uses a moisture sensor in the soil to determine whether the crops should be watered at a given time. The microchip would activate a solenoid when water was needed in the soil, and would release a different amount of water depending on how much moisture is already in the soil. It was found to be beneficial to the crop growth on the farms it was tested on, since the farmers did not have to water the soil themselves and the plants didn’t suffer due to either over- or under-watering.

Literature Survey 3:

A research team from the G.M. Vedak Institute of Technology in India (Yadav et al., 2021) developed a smart irrigation system to aid small and large scale farming operations alike. It aimed to make the system more efficient and automated. They achieved this by using a variety of sensors, such as light, moisture, and water level that takes rain into account). They integrated these sensors using arduino controls. The project uses an Arduino microcontroller (ATmega328 microcontroller, specifically) that periodically reads the soil moisture levels, temperature and sunlight intensity, rain sensors, along with water levels in the water tank, to calculate a logical decision on turning on or off the irrigation system. Based on the different regions it picks up readings from, it can decide to turn on the water pump and only open certain solenoid valves to make sure water flows to the areas that need it, not the entire farm. The Arduino microcontroller has a bluetooth module connected to it, which the mobile app pairs with, creating a wireless connection. It synchronizes live data with the mobile app’s data which the user can then read and send commands to the Arduino system, deciding how to control the irrigation system.

Proposed Work

Plan of Work:

We plan on splitting our work into three section:

- Setting up a microcontroller to communicate with an online dashboard to send and receive data
- Developing the software on the microcontroller to collect and interpret data from the sensors, and validate the sensors through various test cases.
- Creating a circuit and software to control a solenoid connected to an irrigation valve.

Once these are done, we will integrate them together into one product, and test it on the Field and Fork Farm connected to an irrigation valve on their raised beds. Further testing will be done on a larger field with crops on them. We will be working closely with the Field and Fork Farm manager, Noah Long, to get feedback and information.

Target Audience:

Agricultural or gardening organizations who don’t have an automated irrigation system or have a sub-par embedded automated irrigation system aiming to achieve a viable, cost-effective, and efficient solution to managing their irrigation system to save on water, money, and labor.

Technologies:

<u>Sensors:</u>

➔ EK1940 Capacitive Soil Moisture Sensor

➔ DS18B20 Temperature Probe Sensor

- BH1750FVI Light Intensity Sensor

Each of these are analog sensors that can be read using a microcontroller. There are many libraries that support all of these sensors. As cost efficiency is part of our goal, we will be testing various sensors as they can vary by manufacturer.

<u>Microcontroller:</u>

- Raspberry Pi Pico WH: *Allows for more advanced networking and real-time processing*
  - Configured using CircuitPython
  - Will be used as controller to collect data from various sensors and manage logic that controls irrigation
  - All data will be sent to the web server
  - MQTT protocol will be used to communicate with the Pi Pico WH and a subsequent web server

<u>Web Server:</u>

- A Flask web server with MQTT will be used to communicate with the Pi Pico WH.
- Workflow:
  - Pi Pico WH collects and sends data via MQTT.
  - A Flask-MQTT web server syncs with the microcontroller and receives the data.
  - The web server will have a dashboard showing the live data and either an API or logical button to send commands back to the microcontroller using MQTT.
  - The Pi Pico WH listens for these commands and responds accordingly.
- Front-End: *Display sensor data on a dashboard and send commands to microcontroller*
  - HTML, CSS, JavaScript

- Back-End: *Host the Webpage, handle MQTT communication, and API endpoints*
  - Python: Flask, Flask-MQTT

User Stories

As a farmer, I want to avoid giving my crops too little or too much water, to keep them as healthy as possible.

As a farmer, I want a system that waters the crops automatically, so that I do not have to spend time doing it.

As a maintenance person, I want the moisture measurement to record/reflect accurate information, so that it works as intended.

As a maintenance person, I want the system to be uncompromised by typical weather conditions, so that it works the majority of the time without issue.

As a maintenance person, I want to be able to access the soil moisture information remotely, so that I can conduct my work/analysis anywhere.

Project Plan

Phase 1: Microcontroller Setup and Online Dashboard Communication

Goal: Use microcontrollers to start prototyping each component of the overall system and connect to sensors.

Key Milestones:

- Set up Raspberry Pi Pico WH to communicate with an online dashboard from campus
- Set up microcontrollers with various sensors and test to see that they receive valid data
- Set up microcontrollers to control solenoids

Completion Date: February 16, 2025

Presentation 1

Create a presentation that overviews the software and hardware components, and updates the current progress of the project.

Completion Date: February 23, 2025

Phase 2: Sensor Data Collection and Validation

Goal: With the prototyped microcontrollers, fully flesh them out and test them to make sure the system is robust.

Key Milestones:

- Validate communicate between Pi Pico WH and online dashboard
- (Stretch) Move from third party dashboard towards creating our own webserver to handle the data
- Validate sensors and solenoids to make sure they are consistent and reliable
- Begin creating a framework that encompasses all parts to start integration

Completion Date: March 23, 2025

Presentation 2

Create a presentation that updates the current progress of the project and addresses what is to be done and current issues.

Completion Date: March 30, 2025

Phase 3: Integration and Field Testing

Goal: Fully integrate all parts into one microcontroller and test on the Field and Fork Farm.

Key Milestones:

- Integrate sensors, solenoids, and web communication.

- Test and validate on the Field and Fork Farm first on inconsequential spots, then on raised beds, then in fields.

Completion Date: April 13, 2025

Final Deliverables

Fully Integrated Automated Irrigation System

- Working irrigation system with sensors, solenoid control, and dashboard interface, running deployed on the Field and Fork Farm.

Final Report and Presentation

Completion Date: April 20, 2025

Senior Showcase 4/22

Github

Our project will be managed through a monorepo that houses each of our individual sections in various directories. The code that lives on each microcontroller will be organized in different directories.

https://github.com/aanthonyl/Automated-Irrigation

References

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