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499 Research Proposal

Project Title:

Mud Making Machine that Chats Online: Designing an Autonomous, Internet of Things-based Garden Irrigation System

Section I: INTRODUCTION AND PURPOSE OF THE STUDY

When I was very young and very foolish, I read a story about a boy who holds a funeral for his rotting jack-o'-lantern and discovers months later that a new pumpkin has sprouted on the place of the burial, ready to harvest. Feeling inspired, I chose a spot near a creek on my parents' property and left an old pumpkin there, expecting to see a new plant grow up before the next fall. Aside from a desire to try again with slightly more information on the topic, nothing came of it.

Seeing my willingness to learn, my mother agreed to help me on my quest to raise my own pumpkins. As a child, she spent a lot of time watching her grandfather, a talented gardener, work in his garden.

The following summer, I learned how to germinate plants from seeds, water them regularly, and treat them with insecticides and animal repellants. I transplanted the sprouts to my mother's herb garden and raised them there. I also had my first encounters with powdery mildew, a fungus that if left untreated can rapidly devastate a pumpkin patch. First the leaves, then the stems, then the entire stalks began to wither and die. What plants were spared from the powdery mildew were finished off by an infestation of slugs. Again, nothing came of it.

The next year I tried again. I used a seed-starting kit to germinate some sprouts. As before, the powdery mildew ran rampant in the garden. The father of one of my friends from school owned several fields of farmland and suggested that the garden's proximity to a creek was encouraging the spread of the blight. Ironically, I did harvest a single pumpkin that year, but not from the plants I had raised from seed. This was the result of a pumpkin we had left to rot in the ashes of a burn pile. Nothing had come of my efforts but this pumpkin. I was discouraged, but my mother cajoled me with the phrase, "The third try's the charm."

For the third summer of my efforts (fourth, if you count that pumpkin I dumped off near the creek), my grandparents gave me their blessing to use a wide stretch of grass on a property they owned for my pumpkin patch. With the added distance from the creek, better sunlight, a slope well-suited for drainage, and rich soil that had grown nothing but grass for years, I was in business.

A co-worker of my father's who owned a tiller drove his tractor to the location and plowed it for me. Summer break brought hours of hard, sweltering work in the sun. Still, I found it thrilling to walk to my pumpkin patch to find rows and rows of tangled vines and large, dark green leaves. After the fruits began to develop, I soon had to deal with an especially tenacious groundhog that had taken a liking to "sweet pumpkin pie" variety of pumpkins I was raising. I sprayed animal repellent around the perimeter of the pumpkin patch, and my grandfather tried setting a trap for the rodent, but it was never caught.

At the time, I was reading from books for aspiring electronics hobbyists and began to conjure in my mind an electric scarecrow that could frighten away any pesky deer or groundhog that stopped for dinner at the pumpkin patch. I imagined that I could set up a tripwire or a motion detector that would trigger a speaker to play the sound of a gunshot whenever an animal tried to graze on my plants. But for all my fantasies of building some elaborate contraption, all I ever did to thwart these animals was to spray more repellent.

Three summers of trial and error were worth it in the end. When the harvest came, I proudly hitched a wagon to my father's lawn tractor and transported well over a hundred pumpkins of sizes great and small from the property. I sold some of my produce to family and friends and gave pumpkins of gratitude to the people who had helped me along the way. Something had come of it after all.

Now I am a university student pursuing a degree in electrical engineering, but I have not forgotten the pleasure of growing vegetables out of the soil. I do not have as much time to invest in gardening as I did in grade school; a problem, I suspect, that many other "would-be-gardeners" share.

The K-12 private school I attended required that every high-school senior write and present a twenty page "senior thesis" of a topic of each’s choosing before a board. I chose Internet of Things (IoT) Security as my topic and later began considering what kind of IoT devices would make my own life easier. I considered that a sensor could be made to measure soil moisture. If I had a Wi-Fi connected device that could accomplish the same thing as my multimeter, I could measure the resistance of the soil by placing two metal prongs in the dirt. A higher resistance would indicated a smaller amount of water in the soil. I discovered later, as one usually does after conceiving of an invention, that the item already existed on the market.

The idea of a moisture sensor returned to mind when I saw a YouTube video on a channel called "Practical Engineering." In this video, a civil engineer named Grady Hillhouse designed a garden bed system that allowed him to measure the light and moisture levels of plants growing beside his house. Inspired, I wanted to create a similar system that would transmit its data wirelessly.

I later realized that I had misunderstood Hillhouse's design. Hillhouse used an Arduino shield that added an SD card slot to his device. The Arduino would write the data it was gathering to an SD card, which Hillhouse would remove when he wanted to see how his plants were doing. My goal, by contrast, is to create a similar system that transmits the data it gathers to a web-based server.

There are two obvious advantages of making the irrigation system web-based. First, the gardener will have an ability to check on his plants from any computer with an internet connection, which would be faster, easier, and more convenient for the gardener. This also would add an ability to check on one's plants while away from home or travelling. Second, should the irrigation system be damaged or destroyed, a web-based system that stores its data on a separate server will not lose its data. Considering that the system will be placed outdoors and expected to run in summer heat and weather, the possibility that the system will need to be replaced (preferably without lost of prior data) should be taken seriously.

The system could possibly be enhanced to help the gardener control animal and insect pestilence. I have used smartphone apps in the past that attempt to repel mosquitos using high frequency sounds. I have also read that homeowners can use devices that play certain high frequencies to repel starlings from their property. As such, the device could be given a speaker to play an animal-repelling noise to provide the gardener with possible alternatives to using chemical repellents and pesticides. An alternative method, if feasible, would not only do less harm to the environment, it might also prove to be less expensive when the cost of the power consumed is compared to the prices of repellents and pesticides. It could certainly save the user frequent trips to the garden supply store. However, all of this is mere speculation until more research is done. The tasks of watering and recording data will be prioritized over these other possible applications, but they will not be ruled out at this time.

My intention is to complete this project with an autonomous, web-linked garden bed. It remains to be seen whether my design will be economically practical. But, assuming success, I believe the project could be put to some good use.

There may be some charitable applications of this system. While many organizations offer non-perishables to the poor, often donating canned food, some organizations work to provide the needy with fresh produce. A system which reduces the amount of time a gardener must dedicate to the vegetables in his or her garden would be useful to the volunteers of such organizations.

As for myself, I hope to learn how to create my own IoT imbedded systems. I aspire to be something of a polymath; thus, one feature that draws me to this project is the wide girth of disciplines that intersect on this application. To complete this project I must study principles from several disciplines. For example:

* I must learn more about web development to design a web-based system that receives, stores, and transmits data to the irrigation system.
* I must learn more about plant biology to understand how to moderate the water given to each plant.
* I must learn more about programming to develop the software required to control the irrigation system.
* I must learn more about electronic circuitry to connect the components together.
* I must learn about power systems to supply the system with electricity.
* I must learn more about differential equations to adequately regulate the temperature of the system's electronics so as to prevent overheating.
* I must learn about fluid dynamics to implement the pump system that will carry water to the plants.
* I must learn about probability and statistics to interpret the data and the trends of the data produced by my experiments.
* I must learn about agriculture to discover how the irrigation system might best be put to practical use.
* I must learn about meteorology to learn how to account for the possibility that excessive rain is to be expected at a site that is due to be watered.

All of these disciplines, and likely others, will provide important insights in the design of this system.

SECTION II: STATEMENT OF THE PROBLEM

An automated irrigation system can save much of the gardener's time, conserve water, and prevent plants from being drowned, washed out, or exposed to mold or fungus by excessive watering.

Gardening, like any hobby, can consume a large amount of a person's time, especially when unexpected problems appear. Even a short period of neglect can quickly undo all the progress made over a long period of carefully nurturing a garden. I suspect that many would enjoy the task of developing a garden and harvesting fresh fruits and vegetables for themselves, if only they had the time.

Gardening teaches individuals to take care of their property and their environment. One sprays his insecticide with the knowledge that the same chemicals that will kill the pests devouring his plants will likely be absorbed into the vegetables on his own dinner plate. Such is one example of how the task of maintaining a garden can encourage a kind of environmental consciousness. And what is done with the space one would devote to gardening if one had the time for gardening? Historically, home owners in the United States have been encouraged to devote great sums of time, money, and water in the care of a grass lawn.

The grass produces little. It grows, and then it is chopped down. Property owners are encouraged by society (and sometimes bullied by their home owners’ associations) to use fertilizers to keep the lawn growing. Gardening can be used in suburban and even in urban settings as an accepted alternative to regulating patches of grass. If these would-be gardeners exist as I suspect, there could be an environmental impact of their absence. Still, the amount of time consumed by the hobby of gardening remains a valid reason not to bother planting a garden. One purpose of this project is to reduce that amount of time.

Based on my own experience in the garden, I know that gardeners can reduce the amount of time they spend tending their plants by designing their garden in anticipation of future threats. Laying newspaper below fresh soil and building a perimeter around the garden reduces the amount of time the gardener must later spend weeding the soil. Building a fence around the garden reduces the amount of time the gardener will need to invest in applying animal repellent (and reduce the amount of harmful chemicals used). But there is a vital task to the maintenance of the garden which must be regularly, sometimes even daily, attended to regardless of these threats: watering. The goal of this project is to automate the task of irrigation and thus reduce the amount of time the system's user will need to invest in personally watering the garden.

Ecclesiastes declares there is nothing new under the sun (see Ecclesiastes 1:9). And there is nothing new about irrigation systems. Mankind has long understood the value of designing systems to drain water into soil. The advantage of an irrigation system controlled by an electronic device is that the device can precisely measure out the amount of water due to each plant. While a gardener pouring from a watering can is mostly doing guesswork to water adequately but not excessively, a machine can calculate the desired volume with far greater accuracy.

We don't need fewer gardeners. We need more efficient gardeners. This system will not totally eliminate the need for a gardener's intervention. For example, no attempt will be made in this project to create a system that will autonomously weed out a garden bed. Rather, this system might help to shift the gardener's efforts from nurturing germinated plants to creating new gardens and addressing the unexpected and often more dire problems.

A question of practicality remains. Is all of this worth it? Will an internet-connected irrigation system save the user enough time and yield enough produce to justify its expense?

SECTION III: APPROACHING THE PROBLEM

To determine whether this system is practical, the value of all produce that is harvested must be compared to the value of the produce grown in a typical garden of the same dimensions. Because the purpose of this system is to save the gardener's time. The value of a user's time will be taken into account in the analysis. Therefore, two garden beds must be constructed:

1. A web-connected automated vegetable gardening bed that must accomplish three tasks:

One: Collect weather, and soil moisture data at the site of the garden

Two: Transmit data to a web server where it can be accessed by the gardener

Three: Autonomously irrigate its plants

1. A "control test" vegetable garden bed with identical parameters to the autonomous system (length, width, sun exposure, plants, etc.) with the exception that it will be watered by traditional means (by hand with a watering can). A watering schedule and instructions for watering will be created to ensure consistency for the experiment's duration.

To support the autonomous garden bed irrigation system, some means of supplying electrical power, water, and an internet connection must also be implemented. The system must be robust enough to operate in summer heat and weather and have a water-resistant shell to protect all electronics from rain and other weather.

Close records must be kept of both systems’ water consumption, as well as any other regular purchases made to maintain the two systems.

Power will most likely be supplied by connecting the system to a wall outlet. Another option is to generate power at the site. Solar panels, or wind turbines could be used to this effect. Generating power at the site would increase the cost of construction but would decrease the expense of running the device. If this is desired, a battery will be kept at the site. The power generation method would charge the battery, and the battery would supply the irrigation system with power during times when the system is not generating power (night time or cloudy weather in the solar panels’ case).

To supply the system with water, a solenoid valve could be attached to a water spout and a hose run from the valve to the irrigation system. The irrigation system could turn the valve on and off to regulate its water. If water cannot be supplied to the site by a hose, a water reservoir tank could be placed at the site and water could be drained or pumped into the soil from this tank. The reservoir would be filled by hand, and each amount added would be recorded as an expense.

Wire fencing will be placed around both garden beds to protect the experiment from interference from animals. If necessary, pesticides and fungicides may be used to protect the plants. If used, all chemicals must be allotted in equal measure to both garden beds, and the expenses must be recorded for each.

On the web-side of the system, an interface on a webpage should be created for the user to clearly see the state of the garden's plants: water, light intensity, humidity, etc, as well as the decisions made by the irrigation system thus far: when water was applied and what volume of water was used.

With the university's permission, I would like to create an autonomous garden bed on Milligan's campus. This garden bed could be used by the university to raise vegetables to be served in the campus cafeteria or for public service.

Milligan has a heritage of student-led projects leaving permanent developments on the university's campus. The brick walkway between the visitor parking lot and the sidewalk by Blowers Boulevard is the result of a project initiated by Milligan's SGA. A piece of a rock engraved with the first words of the book of John sits in front of Milligan's Gregory center. If the guide who led me on a campus tour before I was enrolled at Milligan is to believe, this engraved rock was the result of a project started by a student. Even the Paxson building, originally Milligan's student union building, was funded and constructed, largely by Milligan faculty and students. Student-built garden beds already exist on Milligan's disk golf course, created by a student-led agriculture club in 2017.

The system I intend to build could be implemented anywhere on campus with direct sunlight, or a system could be developed to record data in flower beds that already exist. Currently, this is mere speculation of how the project could grow after a functional system has been developed. What follows is a tentative plan for creating a functional, autonomous, internet-connected irrigation system:

1. Develop a system that can wirelessly store data in a web-based SQL server or some other web-based platform.
2. Develop a system that can take measurements and store them in the web-based platform.
3. Develop a system that can both send and receive data from the platform.
4. Develop a system to irrigate soil, using the system's measurements and known data about the plants being raised to determine the volume of water to be added to the soil.
5. Implement systems to connect the irrigation system to the internet and to supply the irrigation system with electrical power, and water.
6. Build a case to protect on-site electronics from weather and heat.
7. Construct two garden beds for testing: one to test the imbedded system, and the other as a control test.
8. Raise vegetables of the same variety in both garden beds. Time, money, and water spent in each bed should be logged.
9. Harvest and compare produce between both beds.
10. Determine whether the control or the automated irrigation system was the more cost-effective solution

I have explored several options for the system's "brain". The brain must include a microcontroller that can read inputs and send outputs. The brain must also have some means of transmitting its data to the internet. The first option I explored was a third party "UNO" (practically identical to an Arduino UNO). The Arduino by itself cannot connect to a WiFi network, so I tried working with an ESP8266 module. The ESP8266 is a microcontroller in its own right, but it can be used merely to give a separate microcontroller access to the internet. After making several unsuccessful attempts with this device, I ordered a package of NodeMCUs. The NodeMCU is an Arduino-like development board that includes a built-in ESP8266. Conveniently, the board is programmed using the Arduino IDE software. Just like an Arduino, it can be programmed to read inputs and send outputs. The NodeMCU can also generate webpages.

I intend to advance this project to 499B and then to the 499C level. After the experiment is completed a paper will be written to disseminate its results. When completed, I will present my research at the 2022 Rise Above research conference to fulfill the presentation requirements of this project.

SECTION IV: PRELIMINARY REVIEW OF THE LITERATURE

"Arduino Garden Controller-Automatic Watering and Data Logging." YouTube, uploaded by Practical Engineering, 2 April 2015, <https://www.youtube.com/watch?v=O_Q1WKCtWiA>

Grady Hillhouse is a civil engineer who produces educational YouTube videos about topics in engineering. This video, in which Hillhouse creates a system that records soil and light data in his garden bed, was the inspiration for this project.

Groenfeldt, David. *Water Ethics: A Values Approach to Solving the Water Crisis*. Routledge. New York. 2013. Print.

David Groenfeldt’s book *Water Ethics* outlines the ethical concerns of water conservation. The book contains a section on the ethics of irrigation. This book will be valuable to the project for whatever guidance it can give on the ethical consumption of water.

Laffan, Jennifer. Smith, Peter. *Irrigation Measuring and Monitoring*. Department of Primary Industries. New South Wales. 2015. eBook.

The New South Wales Department of Primary Industries book, *Irrigation Measuring and Monitoring* is the first book in a series of three on the subject of irrigation. The book offers both an outlook on how irrigation works as well as a practical guide to constructing an irrigation system. It also has a section on the environmental impact of irrigation.

Robbins, Paull. *Lawn People: How Grasses, Weeds, and Chemicals Make Us Who We Are*. Temple University Press. Philadelphia. 2007. Print.

Paul Robbins’s book, *Lawn People,* explains the ecological dangers associated with using chemical fertilizers and the history behind modern lawns. I am interested in this book because I am interested in comparing the expense of an automated irrigation system to the maintenance of a grass lawn. The book contains a chapter on alternatives to grass lawns and encourages homeowners to raise gardens of plants native to their home’s ecosystem.

Thakur, Manoj, R. *NodeMCU ESP8266 Communication Method and Protocols: Programming with Arduino IDE*. Kindle Ebook.

Manoj Thakur's eBook provides concise introductions to the NodeMCU's features as well as to different data transfer methods. Thakur's book also includes code examples. I am wary of Thakur's book because of the similarity in some of the book's chapters include identical text to concept introductions I have read on unaffiliated websites. I think it is likely that segments of Thackur's book are plagiarized or have been plagiarized.

Welling, Luke. Thomson, Laura. *PHP and MySQL Web Development Fourth Edition*. Pearson Education. 2009. Print.

This book teaches the reader how to create dynamic websites using the PHP language and the MySQL data management system. Because part of this project involves storing data on the web and creating a website to display this data, the information in this book will be valuable to the project. The book contains code examples and detailed explanations of concepts.

Wirzba, Norman. *The Paradise of God: Renewing Religion in an Ecological Age*. Oxford University Press. New York. 2003. Print.

The Bible describes a God at work restoring a fallen creation to a state of paradise. I am interested in how the work of the gardener can be performed as an act of religious devotion, and so is Norman Wirzba. Wirzba’s book *The Paradise of God* offers a religious view of ecology. The book outlines how gardening, among other activities in nature, can be a spiritual activity.

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