TP-D3: Project Report

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Soil Moisture Monitoring for Proper Lawn & Plant Care

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Introduction

People have various reasons why they care for their lawn and plants. These reasons include improving mental health, obtaining a sense of self-fulfillment via caretaking, or just trying to 1-up the neighbor with their landscaping skills. Additionally, there are many reasons why someone may not be able to take care of their lawn, or even their plants, to the extent they want to. These reasons could vary from having a packed schedule, to not understanding how best to care for the plant, or just being forgetful. Not understanding a plant and forgetting to care for it in a timely manner can lead to underwatering or overwatering. On the other hand, someone could have a great understanding of how to care for their plant but are looking for a way to streamline the process. Our product aims to help all individuals provide the necessary plant care to make their home green and lush and avoid issues that can drain a wallet, all while giving access to the resources someone would need for building a knowledge base on the subject.

Problem characterization

The first problem at hand, overwatering, is a common issue among people who are new to caring for house plants or their lawn. For house plants, overwatering can result in various problems that can be deadly to a plant. One of these problems is waterlogging the soil. Water logging is an issue where the heavier soils retain water for prolonged periods [1]. This issue prevents roots from absorbing the oxygen that is necessary for healthy plant growth and can lead to a domino effect of issues. This moist soil environment can slow the growth of the plant, causing yellowing of plant leaves, and is a perfect place for fungi and mold to grow. If left unchecked, this can create a very deadly environment for a plant. Even one of these issues can start the process of root rot, the name given for any affliction that causes root deterioration and can be a chronic issue. As stated by the Missouri Botanical Garden, “damaged roots have little defense against the entrance of rot causing soil organisms, and so the plant dies of root rot.” [2] One of the solutions for avoiding this is watering only when necessary.

When overwatering impacts the lawn, it is impacted in the same way a house plant is with a few additional issues added to the domino effect of creating that deadly plant environment. Too much water will not only cut oxygen from the root systems; it can also create the perfect environment for weed growth, fungi, and insects, while causing mushy soil, bare patches, grass thinning, and thatch build up [3]. Welcoming weeds into the yard is like inviting the classroom bully to an unsupervised chess club after school; someone will get their lunch money stolen. Weeds compete for the vital resources a lawn needs to flourish, and once they have taken root, they tend to spread quickly. The competition for sunlight, nutrients, and water can cause the grass to be malnourished, making lawn more susceptible to fungi, diseases, drought, and insect infestations [4] [5].

Weeds are an invasive nuisance, but they are not the only enemy to a lawn. A mower can be just as combative to the success of a green lawn, as it can be helpful. If a lawn is getting too much moisture and mowing takes place, the cut wet grass will stick to the undercarriage of the mower. Over time this grass will promote the growth of fungi and mold within the undercarriage of the mower, on the mower's blades, and around the mower's wheels. Using a mower afflicted with these issues will spread that same mold and fungi to your lawn, causing the development of Brown Patch Disease [6]. A disease that will cause yellowing and bare patches, along with hurting a wallet as badly as it hurts the grass. Also, mowing wet grass when the soil is muddy can cause soil damage due to the machine's weight. As you mow, soil can be compacted and riddled with ruts which can damage roots and hinder grass growth [6]. Due to this, it is important to wait until the lawn has an optimal amount of moisture before mowing; just don't wait too long before giving the lawn a trim.

Waiting too long to trim can cause grass to get unruly and tall. When grass is too tall, it can trap moisture and cause thatch to build up. This trapped moisture can aid in the worsening of previously mentioned issues such as root rot, insects, and weeds [7]. Mowing this tall grass will lead to the buildup of thatch. Thatch is often a sign of overwatering and can cause yet another domino effect of issues. A thatch layer can be thought of as the layer existent at the base of the grass. It is interwoven with the top layer of the lawn's soil and is consistent of dead and living grass, roots, shoots, stems, and leaves. This buildup starts when the lawn produces new grass faster than organisms can break it down and is not necessarily a bad occurrence. Some thatch is healthy for the lawn, as it provides insulation for the root systems in times of temperature fluctuation and provides support to the soil by preventing soil compaction and soil shifting [8]. Peter Landschoot, Professor of Turfgrass Science at Penn State University, recommends thatch layers be no more than a half inch thick [8]. Though, too much thatch can lead to harmful effects, especially when overwatering occurs. Thatch can aid in creating the deadly plant environment that overwatering produces by accelerating the formation of fungus, weeds, and insect infestations.

Now that the expansive topic issues of overwatering have been covered, let us touch up on another major issue that impacts lawns and house plants. This issue is one that often impacts someone with a busy schedule or who is forgetful, the topic of underwatering. Signs of underwatering in house plants include wilting, slow growth, and discolored leaves [9]. If left unnoticed for too long, the plant will die. Wilting happens when a plant does not have enough water to pass through its cells and can cause closure of the pores in the leaves. Closed pores prevent the plant's ability to take in carbon dioxide, an essential nutrient to the health of the plant [9]. Be careful when using wilting as a sign for watering. Plants will often start to look wilted in times of high temperatures due to heat stress. Once the heat subsides, the plant should regain its strength and return to looking healthy. If not, be sure to give it some water or you may stunt the growth of the plant. The longer the plant goes without water, the less likely it will be able to regain its normal growth rate. The period of recovery can vary among plants due to varied tolerances of extreme conditions [9].

The final symptom we will cover for underwatering house plants is leaf discoloration. This symptom can cause confusion for a new green thumb, as it is also an exhibited symptom of overwatering. If unsure which of the two is causing the issue, be sure to feel one of the discolored leaves. An underwatered plant's discolored leaves will have brown edges, feel lighter and more brittle than its healthier counterparts; be sure to check if other leaves are wilted or yellow and curling, too [10]. An overwatered plant's discolored leaves will have yellow discoloration and feel a bit heftier than the healthier leaves [10].

When it comes to underwatering lawns, yellow discoloration, brittleness, and slow growth are still present issues. A straightforward way to test for underwatering is by simply walking on the lawn. If footprints remain noticeable for a few minutes after walking on the lawn, then you are not watering enough [11]. Due the difference in environments, lawns can experience more issues than a house plant can. Issues include Ascochyta leaf blight, microbial death, yellow to brown discoloration, and dormancy.

Ascochyta leaf blight is a fungus that is found during cool to hot weather changes in lawns with short roots caused by poor watering practices [12]. You can identify this issue by the yellowish color present in the patches afflicted. If caught in the earlier stages, it can be identified by yellow discoloration at the center of grass blades [12].

Microbes are an essential part of a lawn's ecosystem, as they are responsible for a large part of nutrient exchange within soil. The term 'microbes' is a blanket term referring to many microscopic organisms such as bacteria, amoeba, and protozoa; along with larger organisms such as earthworms and smaller insects [13]. As underwatering impacts the lawn, these organisms can die off causing depletion of nutrients within the soil over time. In the short term, this impact can stunt lawn growth and cause grass thinning. If left untreated for the long term, grass will die causing your lawn to change into a barren, dry dust-scape.

The final symptom of underwatering a lawn is grass dormancy. Dormancy is something that many who have lived through frigid winters should be familiar with. When grass goes dormant, they are activating a defense mechanism adapted for drastic environmental changes to help ensure survivability. This is why your lawn is in the same shape it was in before winter hit, as spring rolls around. This defense mechanism causes grass to become a pale gold or brown color due to it slowing down its own metabolism for energy conservation in suboptimal growing conditions [14]. These conditions include snow, drought, freezing temperatures, and extreme heat. As conditions return to optimal levels, grass will return to its normal growing habits.

The number of issues that can arise from simply watering too much, or not enough, can be extremely overwhelming. Especially for someone who is just starting out with plant or lawn care. Our product aims to help in avoiding these issues by tackling them at the root problem, watering frequency.

Proposed Solution and Implementation Strategy

For our class project, our aim was to create a product that helped in the water management of our lawns and plants. As we looked further into the topic, we realized how drastically watering frequency can affect a plant. The symptoms and repercussions of overwatering or underwatering seemed never ending and quite overwhelming. This gave us an idea; what if we can help people learn more about their plant and lawn care, at their own pace, while our software tracks soil moisture levels and notifies them the day the soil becomes dry? The implementation would be a simple addition to our original plan and would only require providing the same articles we sought out within our notification system.

As we started the project, everything was going smoothly. During our first meeting we pulled our ideas together to create a project outline. The project would utilize a Raspberry Pi, moisture sensors, email notifications, and a website. We agreed to utilize Python as the coding language due to its ability to utilize matplotlib with ease. Matplotlib would provide a simple method of visualizing the data for anyone to understand. The website within our GitHub repository would host this graph, along with text that communicated the data in a more digestible way. Then, the Raspberry Pi, along with the sensors, would be used as the workhorse that drove this system. The program running on the Raspberry Pi would be responsible for taking the readings, facilitating notifications, updating the website, and storing the data. Though after the first few meetings, we ran into issues.

As we planned meetings, we realized how little the three of our schedules aligned. We found it nearly impossible to meet for collaboration, which resulted in working individually more than we had originally planned, which added communication mishaps. Birch was the only person who could find time to work on the project during midterms and built a bare bones model of the sensor code for collecting moisture data. Later, as we all found free time, we were hit with more unforeseen events. Austin became sick, slowing his ability to work and to keep up with his other courses, hindering his ability to work on the project. Once Austin recovered, Birch became ill, and suffered the same dilemma. Our worries of successful project completion became very present during this time. After Birch recovered, we were finally able to meet and flush out the project. By this time, we had the full program code and the website ready; we just needed to pull it together and implement notification functionality. As we tested the program, we ran into pathing issues for accessing the Numpy and Pandas libraries and spent that day trying to correct this issue on the Raspberry Pi to no success. By the end of the day, we decided it would be in the interest of time to rewrite our main file to not utilize these libraries. The plan was for Lukas to rework the main file, while Austin started on the report, since Birch was responsible for much of the code. This turned out to be a success and we had the program functioning on the Raspberry

Pi by that next day. From there Lukas worked on the setting up of email notification functionality, while Austin took data on soil moisture levels to ensure the sensors functioned as intended and to build a working model for the product demonstration.

Given the issues we faced, we were still able to successfully complete our project. Contributions to the project were divided amongst us as follows. Austin's contributions consisted of purchasing the Raspberry Pi, setting up the Raspberry Pi Operating system and network settings, TP-D1, TP-D2, creating a project outline, plan meetings, data collection, setting up code environment, sensor calibration, testing product functionality, website verbiage, updating pi with current version of the project code, collect informative resources, and writing the TP-D3 report. Birch's contributions to the project were purchasing the sensors, wiring and calibration of the sensors, writing the code for sensor functionality, setting up the GitHub repository, creating project outline, website setup, run loop setup, testing product functionality, and proof-reading and feedback of deliverables. Lukas's contributions consisted of setting up email notifications, setting up notification conditional logic, creating project outline, setting up the code environment, setting up the GitHub website, rework of get moisture data function, and proof-reading and feedback of deliverables.

Current model functionality is built with the intent of sending one email notification a week to remind the user of mowing, and an email notification once every 8 hours if the soil is dry. The intention of the weekly notification is not to tell the user to mow, but rather give them the information they need to decide on their own. The notification states that they should check the height of their grass. If the grass is six inches long, or more, then they should mow the grass to one-third of the grass height. This notification will also contain additional resource links that the user can use to learn more about caring for their plants and lawn.

The dry soil notification will be sent at the end of the same day the sensors read a dry soil environment. If the user does not water the plant or the lawn by the next day's notification time, another notification will be sent. This will continue until the sensors get an "optimal" or "to wet" reading. For this purpose, we use two separate sensors that are tuned to different thresholds, which allows the software to take non-binary readings of soil moisture levels. Through this method, we can see if overwatering or underwatering has occurred.

The libraries utilized for the project were time, matplotlib, datetime, csv, os, random, math, RPi.GPIO, smtplib, MIMETest, and MIMEMultipart. The packages of time and sleep were utilized from the time library to allow the sensors to take readings in intervals. This allowed for spaced readings while reducing the likelihood of sensor corrosion. Matplotlib was used for plotting the collected data with their corresponding dates. The datetime library was used for tracking the date and time that each soil reading was taken. The csv library was used for storing our data collection, allowing the plot to show past data. The os library is used to update the GitHub repository and website for every reading. The random library was used to help in creating a sensor simulator for testing code functionality without having to use the sensors. The math library was utilized to round our times to the nearest second. RPi.GPIO provided control to the GPIO on the Raspberry Pi, allowing sensor control and functionality. The smtplib was utilized for accessing a Gmail SMTP server, allowing us to send email notifications. Then the MIME libraries allowed us to format the text being sent within the email notifications.

Conclusion

In the end, we accomplished what we set out to do, but we were unable to set up certain functionalities as much as we hoped. Currently the receiver email is hardcoded and does not have input functionality. Additionally, the path to the push.sh is hardcoded and needs to be adjusted within the code to better fit what device it is running on. We did setup up the website and weekly notifications as intended, which was the critical portion of our product. Our product is a functional system for keeping the end user informed regarding the status of their lawn / plants and reminding them when action (mowing / watering) is necessary. The system is simple, and the notifications are brief but informative enough to keep users from making several common mistakes that might be detrimental to their plant's health. The sensors can be easily tuned for different soil moisture levels to allow versatility for different plants or soil types and growing environments. By only watering, when necessary, the end user will conserve water and have healthier, lusher, and greener plants. We have tested the product on our own house plants and experienced no issues using the system. The plants we experimented with appear healthy and have received a better watering schedule than before. Unfortunately, we did not finish the product in time to test it on our lawns, but our success with houseplants seems promising. We believe this would be an excellent product for anyone who struggles to take care of their plants / lawn due to lack of attentiveness and/or uncertainty around their plants' water needs.

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