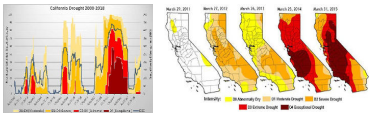
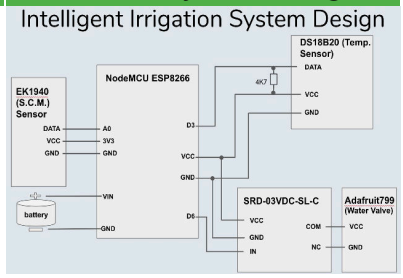
Designing an Intelligent Irrigation System Using Multi-sensors to Improve Water Efficiency

Introduction

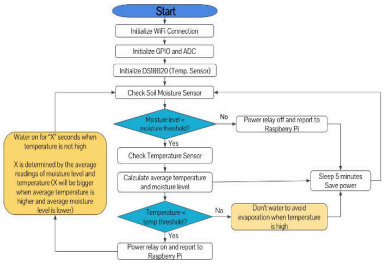
California is frequently devastated by some of the world's most severe droughts. These droughts may start wildfires, which have caused the death of over 102 million trees, resulting in damage of over $600 million. Since over 60% of California water is devoted to irrigation, we sought to create an intelligent irrigation system to conserve water. While a few similar irrigation systems exist, none can provide as accurate watering times.



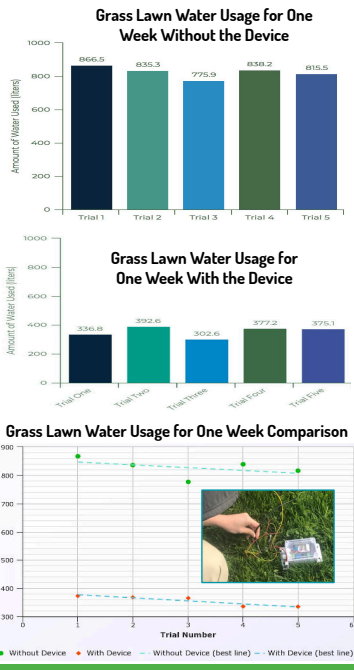
Our New System Design



Watering Algorithm Design



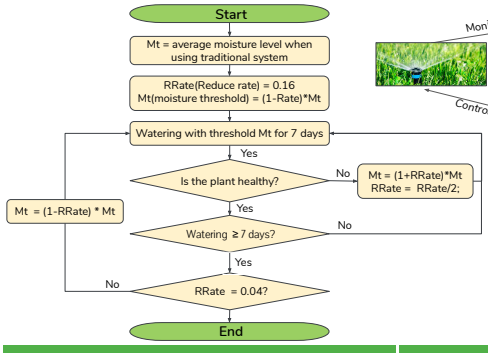
Lawn Experimental Results

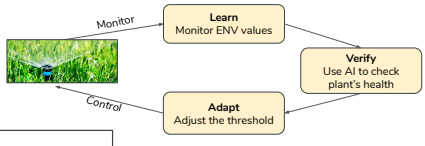


Engineering Goal

Our goal is to develop an affordable device that will create a huge impact on water conservation throughout the state. For this experiment, we hypothesize that when our device is connected to a traditional sprinkler system, we will be able to save much more water than a sprinkler system lacking our device.

A Novel Method of Dynamic Adaptive Algorithm to Acquire Threshold





The soil moisture threshold precision is crucial to plant's health and the conservation of water. This value varies because it is related to area environment, type of soil, exposure to the sunshine and wind etc. This new dynamic adaptive algorithm will find an accurate threshold for you.

Research Questions

1. How do you mitigate the drought problem?
2. Will an intelligent irrigation system be preferable to traditional irrigation systems?
3. How much water will an intelligent irrigation system save compared with a regular irrigation system?

Research Hypothesis

Our hypothesis is that since the device is supposed to optimize water usage using soil moisture and temperature measurement with realistic statistics, there should be a sizable water usage gap between with and without the device. We predicted that our intelligent irrigation systems would save around 50% of normal water usage.

Calculating Water Saved

Best soil moisture threshold value selected is 41%.
The calculated water usage rate is 5.78 L/min.

Using the old timer-based way, the water usage amount in January is:

$$\frac{5\,Minutes}{Day} \times 30\ Days \times 0.204\ \frac{ft^3}{Minute} = 30.6\ ft^3$$

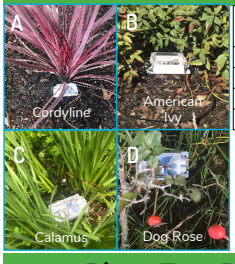
Using the new device, the total water duration in Jan is 64.38 minutes, so the total water usage is:

$$64.38\ Minutes \times 0.204\ \frac{ft^3}{Minute} = 13.13\ ft^3$$

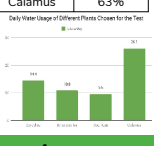
The amount of water saved: $(30.6\ ft^3 - 13.13\ ft^3) \times 28.32\ \frac{Liters}{ft^3} = 494.8\ Liters$

The percentage of water saved: $\frac{(30.6\ ft^3 - 13.13\ ft^3)}{30.6\ ft^3} \times \frac{1}{} = 57\%$

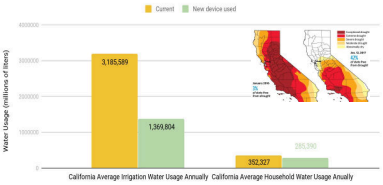
Plant Selection & Setting



Plant Type	Threshold Value
Cordyline	41%
American Ivy	33%
Dog Rose	29%
Calamus	63%



Water Usage Impact in Each Household and in California (Rough Estimate)



If our device is implemented throughout California, there will be around 1.6B m^3 of water saved and around $35 saved annually in each household.

Irrigation System Comparison

Type	Function	Price Range ($)	Way to operate
Traditional	It is a timer-based system. The user configures to turn on watering at a designated time for a predefined amount of time(ie turn on at every Tuesday for 5 minutes).	25-50	Manually
Smart	It can access the weather forecast online data to schedule the watering. The user can choose plant type and sun exposure information to configure the needed watering time duration. It also provides a smartphone app to control the system. It is customized to your geography area.	130-300	Mobile app
Our Intelligent Irrigation System	It retrieves live data of soil moisture level and temperature and use intelligent algorithm to determine the time and duration of watering to save water as much as possible. It is customized to your plant, your field.	~50	Voice

Experimental Procedure

Finding the Best Soil Moisture Threshold

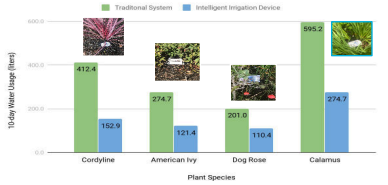
1. Use 5 minute orbit timer to water the old way, and measure soil moisture 100 times immediately after watering
2. Repeat step 1 for 7 days to get the average soil moisture level
3. From Day 8, set the threshold value we got from step 2
4. Use the new irrigation device to water the lawn, and record the watering duration
5. Reduce the threshold by certain percentage every 7 days until the grass appears unhealthy. Once it does, restore to the last good known value to do further fine tuning until an accurate value is found.

Finding the Water Usage Rate w/o Device

1. Stop all kinds of water usage, and read the water meter before watering the lawn.
2. Water the lawn for 5 minutes by traditional way.
3. When watering stops, read the water meter again to find the water usage.
4. Repeat above steps for 7 days. And get the average water usage rate in cubic feet/minute.

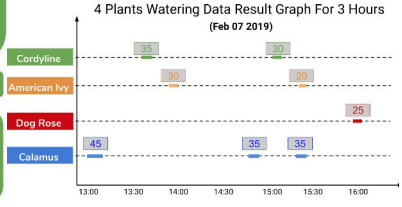
Plant Test Results

Water Usage for Ten Days With and Without Device for Four Different Types of Plants



4 Plants Watering Data Result Graph For 3 Hours

(Feb 07 2019)



Plant Type	Water Start Time	Water Duration (seconds)
Calamus	2019-02-07 13:09:39	45
Calamus	2019-02-07 14:44:33	35
Calamus	2019-02-07 15:21:22	35
Cordyline	2019-02-07 13:31:53	35
Cordyline	2019-02-07 15:01:04	30
American Ivy	2019-02-07 13:56:55	30
American Ivy	2019-02-07 15:24:25	20
Dog Rose	2019-02-07 15:55:39	25

Conclusions & Future Work

- Created an intelligent irrigation system which controls watering schedule based on live data from soil moisture and temperature sensors.
- Designed a novel dynamic adaptive algorithm to acquire the accurate threshold so it can save water as much as possible.
- Applied the device on a grass lawn in the experiment for more than one month, it saves 57% water usage compared to a traditional irrigation system.
- Applied the device on four different plants for 10 days, the experiment results show between 45% and 62% of water was saved.

Overall, the results concurred with our hypothesis that the device will reduce water usage significantly.

Our future work is to add a camera to the device to monitor the state of the plants and use artificial intelligence technology to identify the changes of the plants' health automatically. Thus it will find the threshold with greater precision, leading to save water as much as possible while keeping the plants healthy. The device will work completely without any user's involvement in a more intelligent way.

Devices & Materials

Materials	Price
Arduino ESP8266	$4.78
Gikfun Capacitive Soil Moisture Sensor	$6.44
DS18B20 Temperature Sensor	$2.40
Power Relay Module	$4.79
Water valves	$9.99
Waterproof Cover Case	$4.99

Selected References

1."Are California Municipal Water Rates Too Low to Spur Conservation?" *Master Resource*, 17 Sept. 2014
2.California Water Science Center. "California Water Use." *California Droughts Compared | USGS California Water Science Center*
3."Californians Go Back to Using About as Much Water as Before the Drought." *KQED*, 3 Apr. 2018, w
4.James, Ian. "USGS Estimates Vast Amounts of Water Used in California." *Desert Sun, The Desert Sun*, 21 Aug. 2014.