IrrEEgation: High Level Design

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Flood Irrigation Pylons

Introduction

Flood irrigation is a common practice on the southwestern United States. It involves opening a valve to release water at a high volumetric flow rate. As this water moves through a farmer's field, it takes the form of a thin film, gradually moving across all the land to be farmed.

Problem Statement and Proposed Solution

Improper watering is an unacceptable result of flood irrigation. In a region in which water is scarce, it is unfair to waste water. In some cases, too much water may damage nearby properties. In order to avoid overwatering crops, a farmer practicing flood irrigation must walk out to his or her field at regular intervals for up to 36 hours. Every time, he or she must monitor the distance the water has traveled. When the water has traveled a sufficient distance, the farmer must walk to the valve and manually turn off the water. Since flood irrigation is typically done every two to three weeks, it can be a draining process that takes energy out of the farmer and prevents him or her from getting much needed rest. Furthermore, flood irrigation can only be done when given permission by water authorities. This further takes away a farmer's ability to make his or her own schedule, making flood irrigation more inconvenient.

Instead of these constant manual checks, a system of pylons can do the work for the farmer. The pylons will be equipped with technology that could sense when water hits them. These pylons will then be connected to a central hub. This hub will communicate with a motor controlling the valve, enabling water to be turned on and off remotely. Additionally, a mobile app will be able to see the progress of the flood irrigation, allowing the farmer to monitor his or her crops remotely.

System Requirements

In order to solve this problem, the pylon system has many design restraints and demands that must be met. To achieve this goal, a central hub will allow a user interface, pylon system, and motorized valve system to interact.

First, the hub will need a great deal of processing power since it will be constantly reading and writing data from the pylons, user interface, and motor. Therefore, it should be plugged into an outlet at the farmer's house. It will also need wireless capabilities to interact with the other elements of the system.

Second, since fields using flood irrigation are typically between eight and sixty acres for independent farmer, wireless communication will be needed in order for the pylons to communicate with the central hub. Wireless communication units can be attached to each pylon, decreasing the necessary range, for each one. Additionally, the pylon must be able to sense water. Water sensors come in three varieties: resistivity, capacitive, and neutron interaction. Since the fields of the Southwest are often dirty, a filter should be used to decrease the level of debris in the water reaching the sensor to increase accuracy and durability. The entire pylon should also be covered with some sort of case to keep it protected from inclement weather and make it easy for the farmer to find.

Third, the motor must be able to remotely open and close a valve. There are several options for electronic valves, which can be combined with a wireless microcontroller to control the flow of water electronically. A water tank will also be required to hold the water that will be released through the valve in our experiment.

Finally, the user interface must be easy for the user to use and understand as well as instructive. Therefore, it should be aesthetically pleasing and inform the user of whether the valve is open or closed, where the water is, and if any subsystem is in danger of losing power. The user should also be able to open or close the valve directly from the app.

System Block Diagram

Overall System

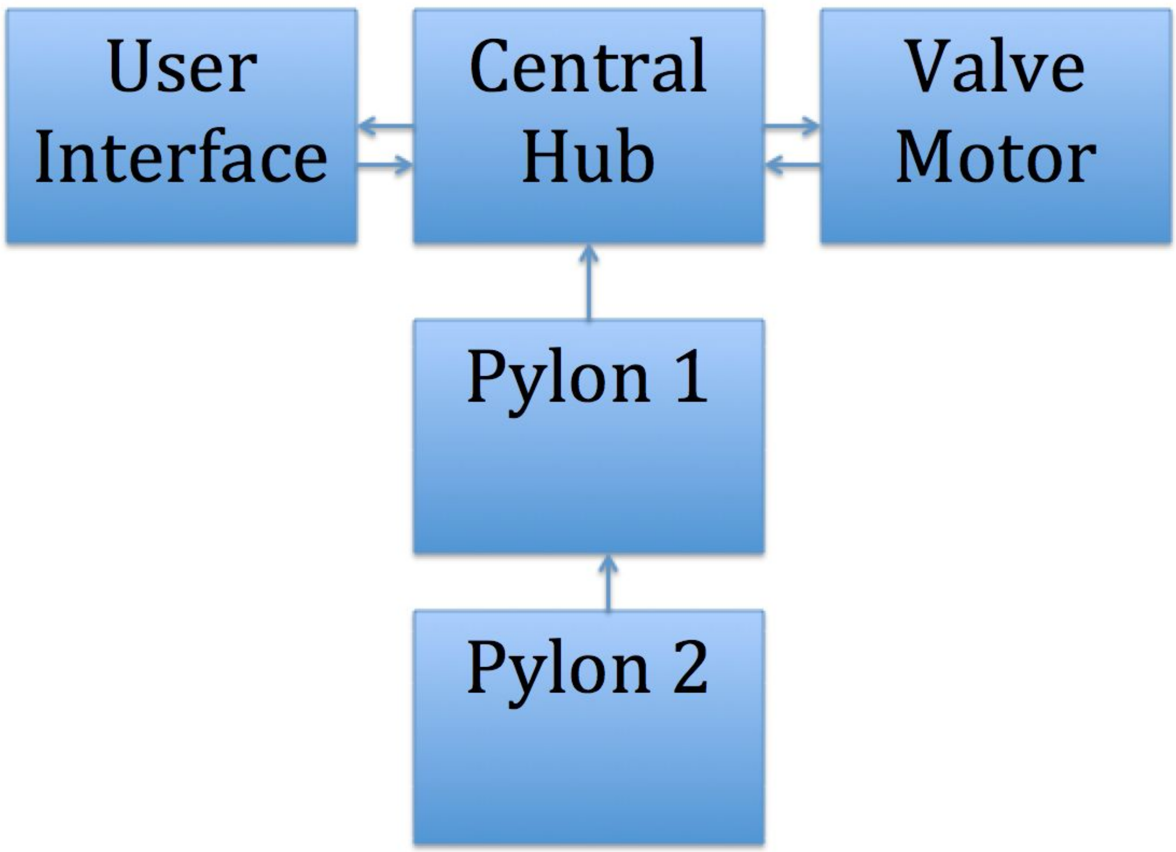

Figure 1. Block diagram showing connections between each subsystem.

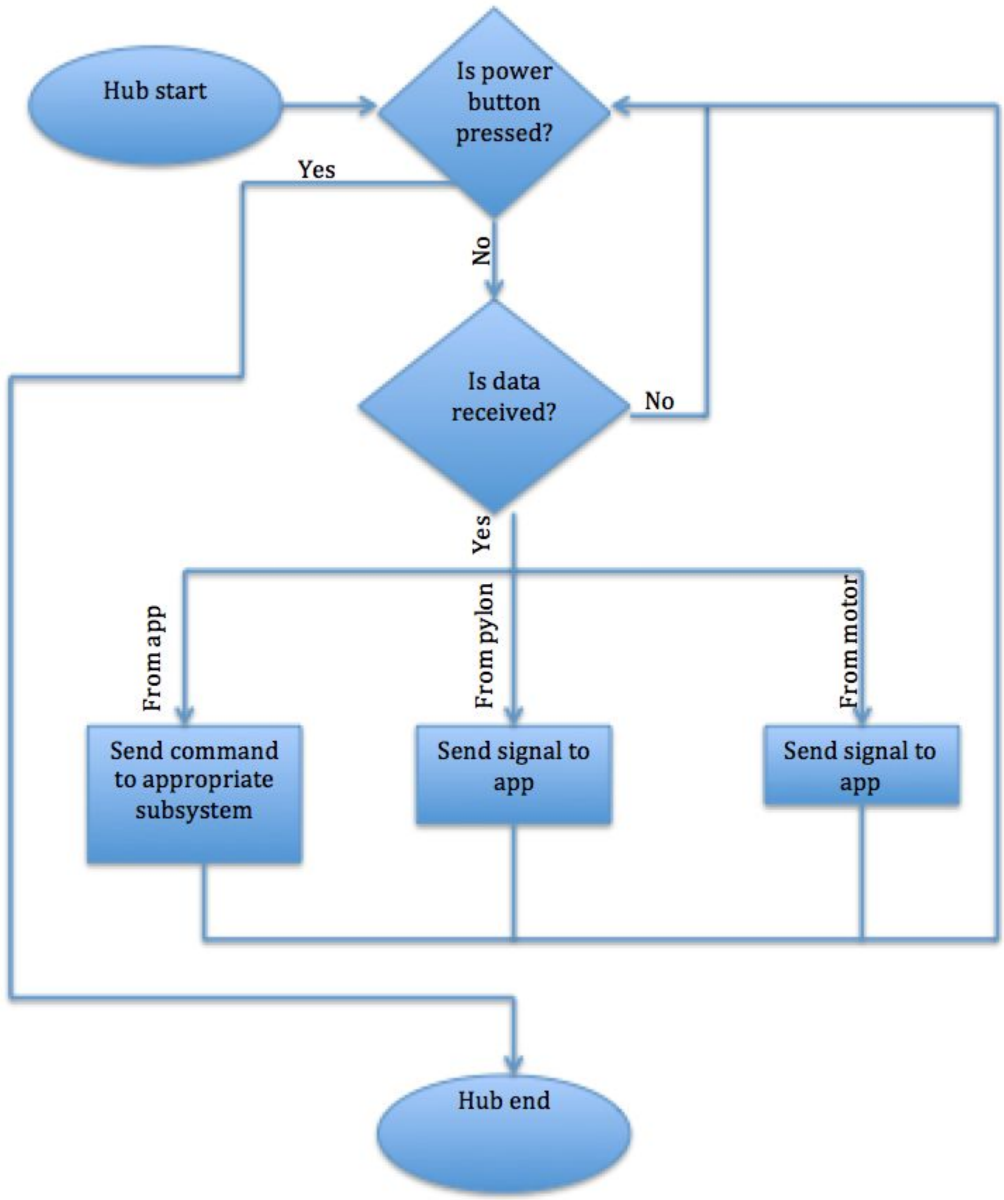

Figure 2. Block diagram for the central hub.

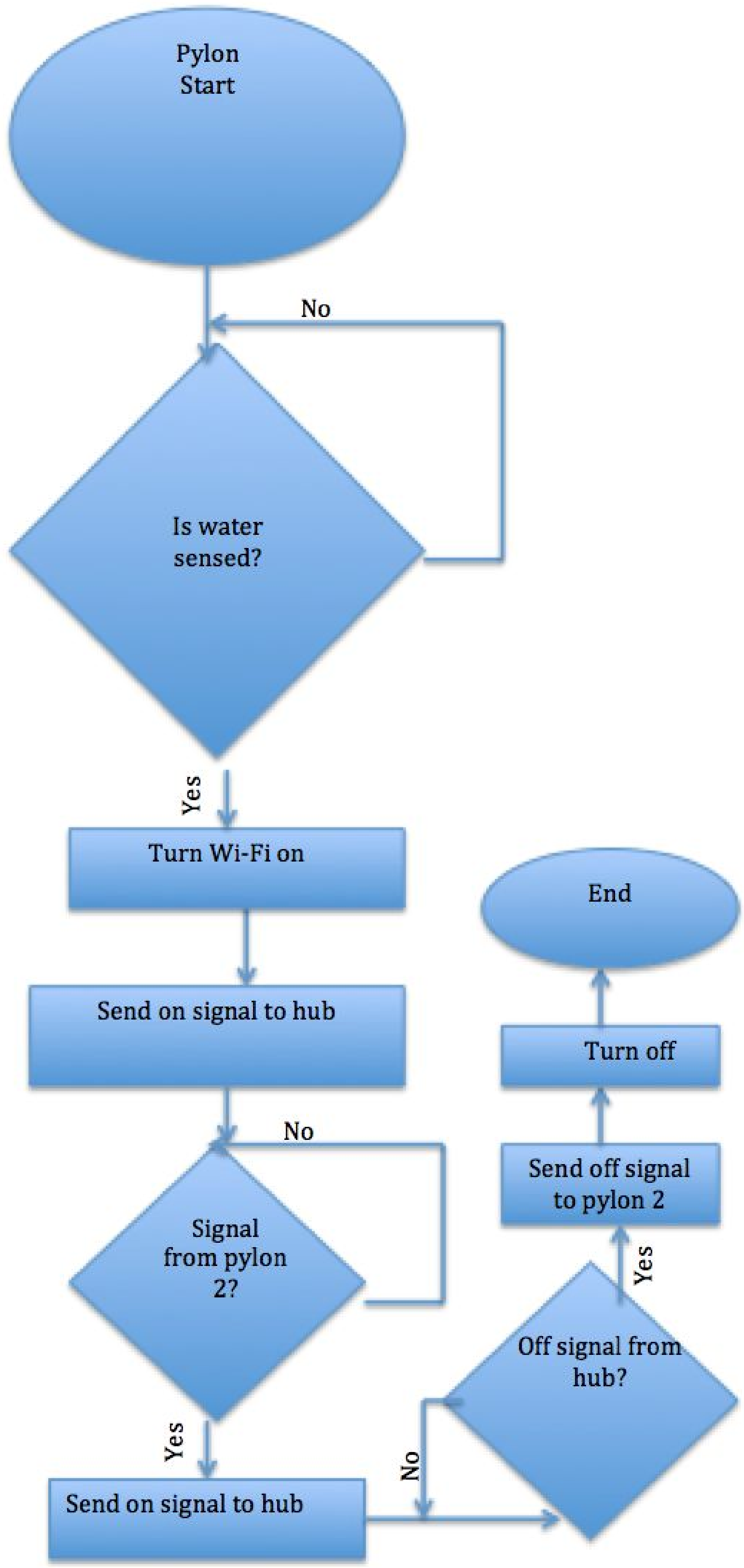

Figure 3. Block diagram for the pylons.

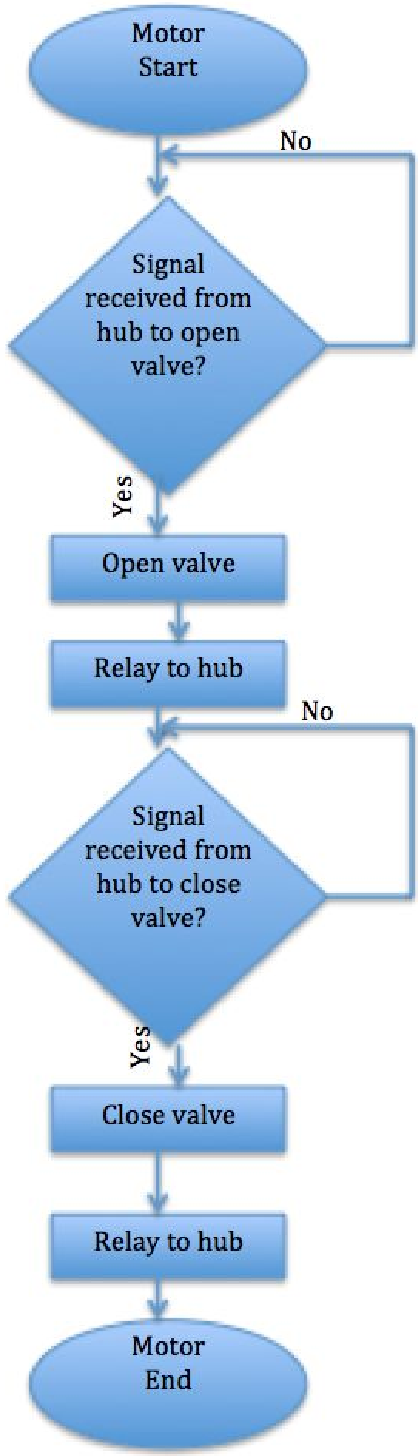

Figure 4. Block diagram for the motor.

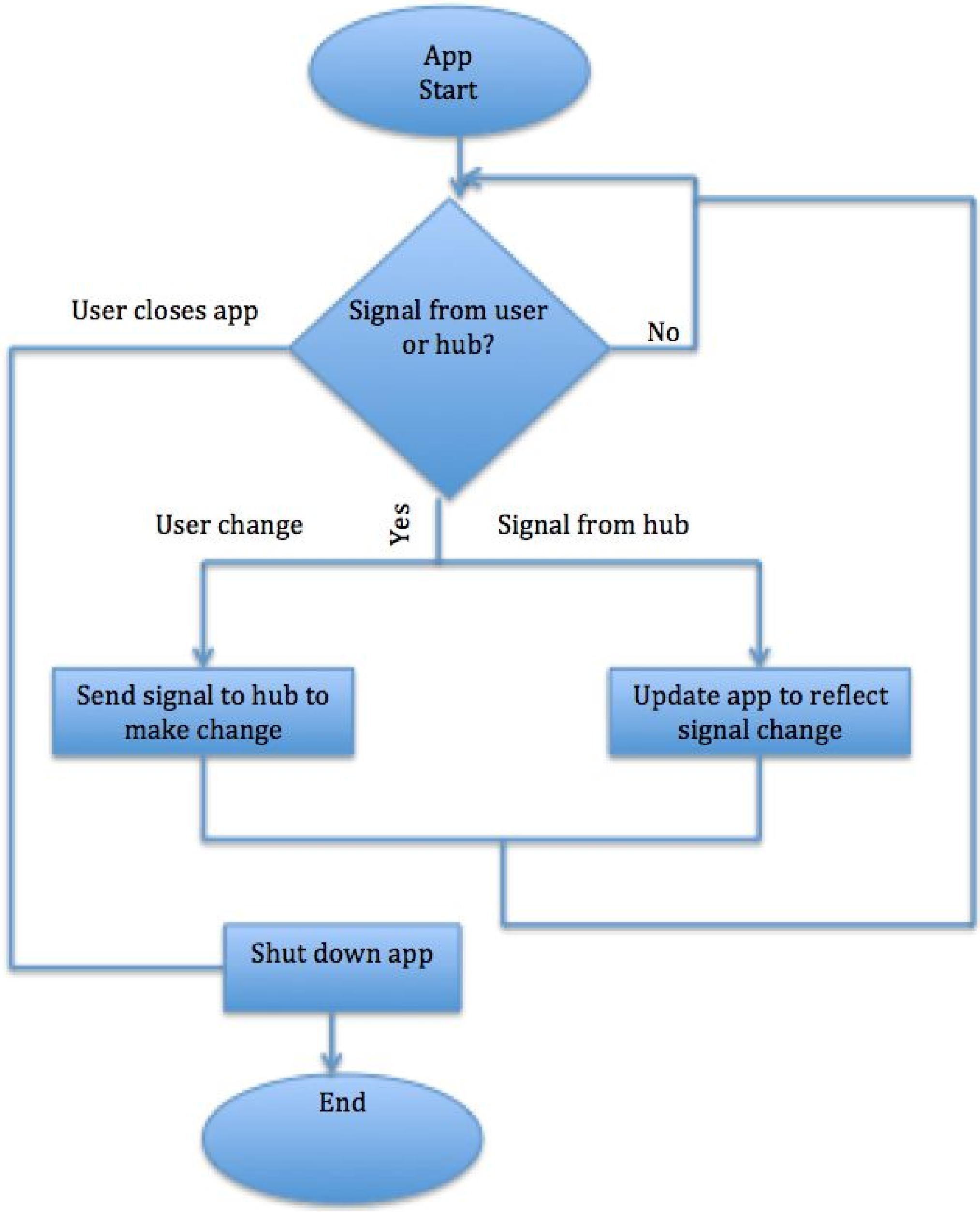

Figure 5. Block diagram for the user interface.

Subsystem and Interface Requirements

When the hub is turned on, it automatically goes into a state in which it waits for a signal to be sensed or for the power to be turned off. If the power is lost at any time, the hub loses its ability to perform any function and the valve automatically shuts. If a signal is sensed by the hub, it will either be coming from the user interface, pylon, or motor. Any signal from the pylon or motor should lead to a change in the user interface sent by the hub. On the other hand, any signal from the user interface should either cause the motor to turn on or off and might cause the pylons to turn off as well.

When the pylon leaves its sleep state, it waits until it senses water or receives a signal from the hub or another pylon. If it senses water, it sends that information to the hub. If it receives a signal that another pylon has sensed water, it sends that information to the hub as well. If it receives a signal from the hub, the pylon should enter the sleep state after it echoes the signal to any pylons further down the chain.

When the motor is on, it waits for a signal from the hub. If it receives a signal to open, the motor will turn on until the valve is open and relay that the opening is complete back to the hub. Conversely, if it receives a signal to close, the motor will close the valve and relay that the action is complete.

Future Enhancement Requirements

This project is a prototype of the product that would be marketed to farmers in the Southwest. The marketable product might have features not present in this design. For example, a pre-existing valve could retrofitted to minimize installation costs. Additionally, this project specifically deals with alfalfa fields, which require only a thin layer of water to transcend the field. For other crops, the pylons could be altered to reflect the demands of the flood. Moreover, materials such as the plastic cone case and cheap solar panels could be upgraded to make the system more durable. Finally, the velocity of water could be calculated based on the time it takes water to travel from one pylon to the next; this feature could be used to better anticipate when water will reach its nominal point.

High Level Design Decisions

In order to fulfill our requirements and realize our design, several design decisions need to be made regarding the various subsystems and how they relate to the system as a whole. First, in order to accommodate for the large size of the field, we need a communications system with a large enough range. Therefore the best option for our design is Wi-Fi, which is cheap and has a range of 300 feet outdoors. This will enable the farmer to purchase the smallest number of pylons possible, reducing cost. For this, we plan on using the ESP32 chip, which is cheap, light, and effective. Currently, the ESP32 is unavailable from the manufacturer, so in the meantime we will use the ESP8266 for development.

Secondly, the hub subsystem will contain a ESP32 chip, which will be responsible for collecting the data from the pylons and the motor and relaying it the app. The hub will also take the data from the app and relay it to the pylons. It will have the pylons Mac addresses preprogrammed into the hub in order to distinguish where the various data is coming from. The hub will require the most power since it is constantly inputting and outputting information. It can be plugged into a wall outlet at the farmer's house to get enough power to operate.

Third, the pylon subsystem needs to be capable of detecting water. In order to achieve this we will use a resistive based water detector, because it is able to easily detect the film of water coming down from the field. We will use the SparkFun Soil Moisture Sensor which works like a potentiometer: when more water is present the resistance between the prongs decreases which increases the current flow. From this mechanism we will be able to determine when the water has passed through the pylon. The pylon needs to be large enough that it fits the ESP32 chip, circuits, and water sensors. For our needs a 6”x6” soccer cone should be used as a case, because it will offer protection for the chips stored inside and easy to locate due to its bright color. Since the water might carry dirt, a filter would be useful to keep the water sensors clean, helping them last longer. To do this, holes could be cut in the sides of the pylon to let water flow, but keeping the majority of debris out of the system. A screen similar to that used in a screen door would be effective for this. Rather than focusing on weight, ground stakes could be attached to each corner of the pylon, keeping it in the ground. The ESP32 chip requires 3.6 V to run effectively. Since the Southwest is extremely sunny, we will use solar panels to charge the batteries for the pylons. The Game Winner Solar Panel Battery Charger provides 6 V, which is more than enough. With good sunlight, the batteries should be charged easily every day. Additionally, four AA batteries will be connected in series to provide 6 V in case the solar panel fails.

Fourth, the motor subsystem will be responsible for opening and closing the valve in order to control the water output. Since we are merely building a prototype, a valve designed for a pipe the size of a garden hose will do. A 12 V DC Electric Brass Solenoid valve allows remote opening and shutting of the valve. Another SparkFun Soil moisture sensor can be used to detect whether or not there is water in the pipe and determine if the valve is open or closed. The ESP32 chip will control the motor and communicate with the central hub. Since the motor requires 12 V, we will use two of the 6V solar panels and batteries together to power the system. The motor will replace a previously existing device for opening and closing the valve, rather than retrofitting a preexisting system.

Fifth, the mobile app subsystem will be the user interface. The mobile app will communicate only with the hub. Since it is connected to Wi-Fi, the app would only work within range of the hub. The hub will relay information such as whether the water valve is opened or closed and which pylons have sensed water. Time stamps will be included to inform the user of when each pylon began sensing moisture. Additionally, the user will have the ability to open and close the valve, although this process can also be automated. Notifications can be enabled to inform the user when key pylons sense water. The coding for the app will be done using the Mac Operating System, because it is easy to program and since most of the people in our group have macs or iphones it’ll be easier to test the app.

Open Questions

There are many ideas in our design that have not yet been realized and that might not work to perfection. First, the ESP32 chip should work up to 300 feet using its Wi-Fi technology, but in practice the range might be shortened. Additionally, the hub needs to be able to sense exactly which pylon is sending the signal that it senses water. At this point, we are unsure how this will be accomplished. Finally, the solenoid motor requires 12 V DC to operate. Currently, we are planning on using primary batteries for this function, but eventually it may be better to use a high quality photovoltaic to provide this voltage.

Major Component Costs

Solenoid valve: $46.95
Soccer cones (12): $4.77
Fiberglass Screen 36”x84”: $5.82
ESP32 chip (4): $16.00
SparkFun Moisture Sensor (6): $5.94
Game Winner 6 V Solar Battery Pack (4): $71.96
Game Winner 6V 4 Ah Feeder Battery (4): $35.96
Camping Stakes (12): $6.46

Total cost: $193.86

Conclusions

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