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Project Title:

Precision Irrigation System

Group & Disciplines

Johnny Nader	*Software*
Majd Nasrallah	*Hardware*
Alexander Semaan	*Networking*

Advisor: Prof. Mazen Saghir - Electrical & Computer Engineering department

Co-advisor: Prof. Haitham Akkary - Electrical & Computer Engineering department

1 Executive Summary

As we are approaching a new era, the world is starting to face new challenges, one of which is the fast growth of the earth's population where it witnessed an increase from "1.5 to 6.1 billion in just 100 years. The population is projected to become around 10.1 billion by 2100" [1]. This challenge requires having enough resources to be able to feed the population, and in order to achieve that, a development of the agriculture techniques is needed, and thus in irrigation systems. To design such a system, some constraints present themselves, such as the size of the used sensors and the unit, the low power consumption, the accuracy of the automation, the ease of the interface, the wireless communication protocol to be used, as well as many more constraints discussed further on.

We propose to solve this problem by implementing a fully automated precision irrigation system that will take measurements using sensors placed in the field, analyze the collected data, and finally take the decision of either irrigating or not, and specifying the amount of water.

In order to be as accurate as possible and to save as much water as possible, we plan to integrate machine learning algorithms in order to analyze the collected data from the specific crops and go about irrigating these crops in the most efficient way possible.

We have planned to create a website where all the collected data would be available to the user, as well as a weather forecast for the next week, and where the user would be able to follow up on how the irrigation decisions would be taken.

What we have accomplished is the completion of a unit that collects data with the use of sensors that are wirelessly sent to the base station, which would be a computer in our case, using Zigbee communication protocol. The data would then be displayed on the website we created and a machine learning algorithm would take the decision, using previously collected data, to take the appropriate actions and irrigate the crops to the most efficient extent.

2 Acknowledgments

We would like to thank our advisor Prof. Mazen Saghir, and our co-advisor Prof. Haitham Akkary for their valuable help in guiding us and observing our work so we stay on the right track. Also, we would like to send appreciation to Dr. Nadim Farajallah, who was of significant help in understanding the process from an agriculture perspective

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3 Introduction

3.1 Motivation

Water, which is one of the most abundant resources on earth, is becoming a precious and endangered one [2]. In addition to that, agriculture is the most important consumer of water, where it consumes around 70% of world's fresh water, therefore improving the irrigation system of this industry will have a major impact on the overall water consumption. Taking a closer look at the currently used irrigation systems, we discover that less than 50% of the water applied to the plants are being used by the latter, and therefore more than 50% of the water is going to waste [3]. Therefore, it is a very clear sign that it is a field where improvement can, and should be done.

3.2 Desired Needs

The objective to be reach, by implementing the desired design is to reduce the water consumption, by improving the efficiency of currently used irrigation systems. The problem with current ones is that they rely only on the farmers' expectations and experience, and not based on concrete data concerning the need of plants for water. By reducing the amount of water lost, we would be reducing the overall need of the agriculture field for water.

4 Requirements and Deliverables

4.1 Requirements and Specifications

The Precision Agriculture System (PAS) needs to achieve the three following requirements:

4.1.1 Maximize Productivity

Maximizing the yield of a field by dividing it into small segments, where each segment's conditions are measured separately, in order to personalize the irrigation per segment, and not under/over water the whole field.

To do so, the WSN should provide real time data regarding the state of the soil and crops monitored, per segment.

4.1.2 Minimize Cost of Production

Minimize the cost of monitoring, by minimizing human labor, and replacing farmers responsible of manual monitoring with sensor nodes.

To do so, the WSN should work for small fields, and scale up to large ones, without losing efficacy, needing minimal maintenance.

4.1.3 Minimize Waste of Water

Minimize the amount of water used to irrigate the field:

- When rain is predicted, no water should be used to irrigate
- When a segment is at the desired conditions, irrigation should be cut to that segment alone

To do so, the PSA should pull accurate weather data, and the WSN should have an adequate resolution of the field: the segment sizes should be adequate.

4.1.4 System Robustness

The Sensor Nodes constituting the WSN should be small enough not to interfere with the farmer’s daily activity, while still capturing the required data, and use machine learning to adapt to the changing conditions.

4.2 Deliverables

The deliverables will be a wireless sensor network that will collect the data from the field and send it to the main station constituted of a server and the decision unit. The data will be collected and analyzed in the server and sent to the user, also a decision will be taken by the decision unit either to irrigate or not, and how much. The WSN dividing the field into segments, these decisions will be per segment, and will take into consideration weather data, and change in conditions per segment.

Hence, the deliverables are a WSN consisting of Sensor Nodes, a Base Station, and a Decision Unit running on a server.

5 Technical and non-Technical Constraints

5.1 Technical Constraints

- Power consumption should be lower than 50mA per node.
- Solar energy should be used in order to sustainably power the nodes.
- The required sensors' input voltages should be 3.3V to match with the board.
- The Size of the sensor node should be less than $30x30x20cm^3$.
- The sensor should pull data every 15 min, conserving battery, yet keeping the data up to date.
- The system should be precise in a sense that it will have an output that is reliable, meaning the output should not have variations of more than 5% for the same input.
- The irrigation system that the client has already deployed should be divided into multiple segments to be able to control the irrigation in specific regions.
- The wireless network should be robust, not have a single point of failure.
- Sensors must be able to form a sensor network communicating with a central node.
- Remote Access to the network must be available through a dedicated webpage.
- The Farmer should have an emergency shutdown button, if the system malfunctions.

5.2 Non-Technical Constraints

- The bill of materials required to build the minimum product designed in this project must cost less than $300 when purchased over the counter in Beirut, at the time of project completion.
- The nodes in our Wireless Sensor Network must not contain any kind of material that could be dangerous or toxic for the soil or crops, Code 3 Plastic (PVC).
- The nodes in our Wireless Sensor Network must be wrapped in a way that is appropriate for a wet and muddy environment as well as harsh weather conditions, IP64 compliant. [4]
- The maintenance required for the power supply (solar panels and battery storage) should be easy to do and non-frequent, over a year before a maintenance check-up.
- The network's security must be complex and reassuring to the clients, since getting access to the network could lead to a lot of damage, switching Zigbee channels and using a firewall to secure the base station. (For instance, a hacker could flood the crops or steal private data from the server, raising an issue of privacy for the client/farmer.)
- The user interface should be simple and easy to use for the farmers to adopt such systems, otherwise they will show lack of interest in a complex system and will most likely stick to their current system since they are familiar with it.

6 Literature Review

6.1 Wireless Sensor Network in Precision Agriculture Application

Wireless Sensor Network (WNS) is the most efficient way to resolve the problems farmer face in Agriculture today, by optimizing farming resources and by guiding farmers to make the proper decisions. The system this paper demonstrates offers real-time information about the crops allowing the farmers to base their decisions on accurate data. Using WSN technology, precision agriculture systems require a solid hardware architecture, network architecture and software process control in order for the precision irrigation system to work properly. [5]

The paper bases its research on greenhouse cultivation for crops in Malaysia. The details on the WSN node architecture provided in this paper is very similar to what our project aims at achieving and could therefore be very useful to help us design our WSN. The WSN in the paper includes implementation of multiple sensors with their wireless communication to a central node; the sensors included are a soil moisture sensor, a temperature sensor for the environment as well as relative humidity in the air. However, the research in this paper confirms the ability to add multiple sensors such as PH, salinity and NPK sensors.

After testing the system, the authors claim that they were able to save on average 1,500 mL per day per tree while getting the same yield. [5]

6.2 "Design issues for wireless sensor networks and smart humidity sensors for precision agriculture: A review" [6]

"The application of Wireless Sensor Networks (WSN) provides a low cost and easy to implement solution for automatic data collection from farmlands" [6]. In addition to that, this paper points out the gaps in the WSN system and the drawbacks that result from the use of humidity sensors, that hold a crucial role for such a design. In addition, this paper goes over numerous requirements of humidity sensor characteristics in a wireless sensor network for precision agriculture. The paper ends by an in-depth comparison of research work recently done in the field of humidity sensor design and performance modeling. [6]

The design this paper implemented is indeed very similar to what we are looking to accomplish.

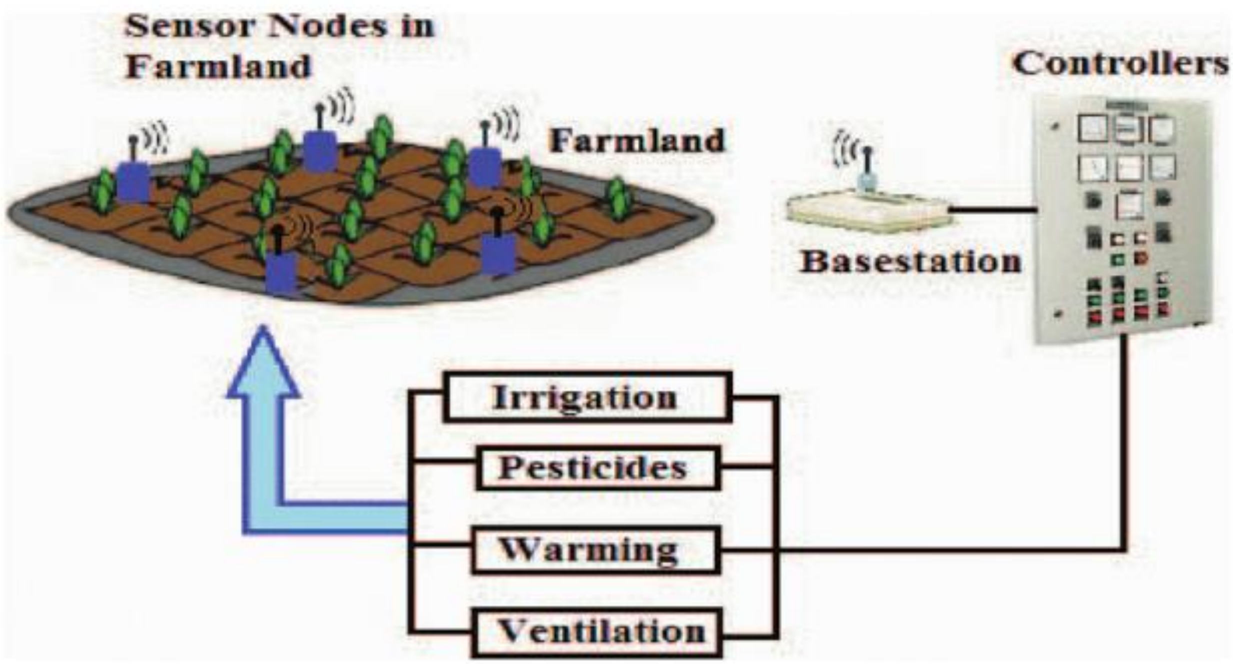


Figure 1: Overview of the Precision Agriculture System

For wireless communication with the base station, Zigbee is employed. Although our design will not implement features such as Pesticides, warming and ventilation, it just shows the multiple opportunities that this system offers. In addition to that, our system will be automated and will not require controllers, however it will need internet connection to servers in order to do the machine learning part to be able to forward commands.

6.3 "A Wireless Sensor Network using XBee for precision agriculture of sweet potatoes (Ipomoea batatas)" [7]

The paper focuses its research on sweet potato crops. The paper bases its studies on two identical set-ups: one is in a controlled environment and the other is exposed to the natural environment. The controlled environment constitutes of a miniature greenhouse in which its humidity, soil moisture and temperature is being sensed. The WSN employed uses Zigbee communication protocol and is connected to a laptop where MATLAB is used to interpret the gathered data. The paper uses a "graphical user interface" (GUI) that is designed in MATLAB in order to display the 3 characteristics that are sensed. [7]

The comparison this paper has made between a controlled and a natural environment is very interesting and very important for us to consider, in order to make sure that the test results that we will get in our project (normally a controlled environment) are also promising.

6.4 Machine Learning

Deep Neural Network are the main area of focus in machine learning recently, and for all the right reasons, they allow for accurate prediction, given sufficient training data. Needing to water or not can be modeled into a classification model. When it comes to classification, most papers agree, after comparing to all the available machine learning techniques, that the two best machine learning algorithms for the job are Neural Networks and Random Forests. [8] [9]

However, S. Dimitriadis and C. Goumopoulos have found in their paper entitled *"Applying Machine Learning to Extract New Knowledge in Precision Agriculture Applications"* [10] , after studying multiple machine learning techniques, noteworthy of which is neural networks, and genetic algorithms, that the models they produce are not understandable by humans. Although the two proposed methods might produce an acceptable result in the long run, they avoided them finding them unpractical. Machine Learning is deemed necessary "because the task of extracting rules is highly demanding and requires the expert to be fully aware of the problem. In some cases, the expert cannot supply information that can be incorporated into the knowledge basis of the expert system" [10]. They concluded by finding long term experimentation necessary to verify assessments made by the chosen model.

7 Applicable Standards

All the components to be used in the project must abide by international standards. Find bellow a list of the relevant standards related to this project:

- **ANSI Y10.5-1968:** The ANSI Letter Symbols for Quantities.
- **ASCII-1967:** The American Standard Code for Information Interchange.
- **IEEE 802.15:** The IEEE standard for Bluetooth, the networking protocol used for signal transfer in this project.
- **IEEE 802.15.4:** The IEEE standard for Zigbee, the networking protocol used for signal transfer in this project.
- **IEEE 308.1969:** The IEEE Criteria for Class IE Electric Systems.
- **IEEE 802.11a:** The IEEE standard for implementing wireless local area network (WLAN) computer communication in the 900MHz, 2.4, 3.6, 5 and 60 GHz frequency bands.

8 Proposed Solution Methodology

In order to design and build the system, we have to analyze the different components constituting it, choosing the best alternatives.

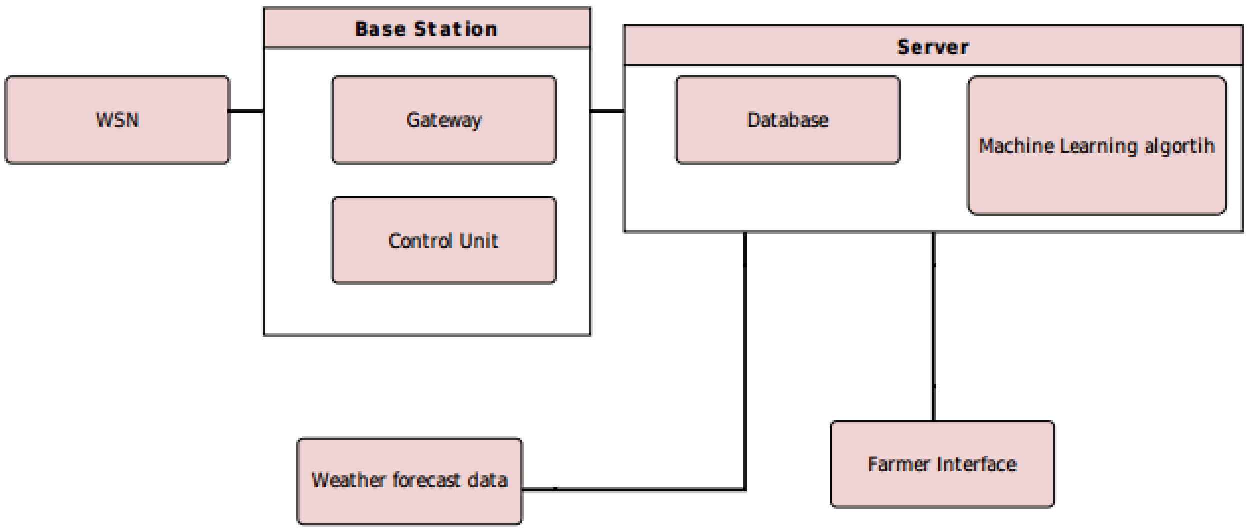


Figure 2: Block Diagram of the System

Figure 3: Diagram of the ordered design steps taken

First, the different sensors that make up each node in our Wireless Sensor Network should be considered. We aim to minimize the amount of water used for each section of the field, therefore we need for each node a humidity sensor, a moisture sensor for the soil, a humidity sensor for the air, two temperature sensors, one being used for the air and the other for the soil, as well as a PH sensor and an electrical conductivity sensor in order to determine fertilizer needs of the soil.

Afterwards, we have to continue our design in a manner that will allow us to connect our sensors to a board capable of processing analog information that these sensors captured and converting them to digital values that will be sent through a communication protocol to the base station, making sure our final product is not power-hungry, but is reliant on an efficient energy source. We have two alternatives for the board that we will be using; we will either use a board that is already available on the market and that suits our needs, or we will have to build one. As for the communication protocol to be used, we have considered Bluetooth 4.0 and Zigbee, and for the powering method we found it most adequate and convenient to use solar energy.

Consequently, we will have to search for various products in the market and check if they meet our design's requirements and needs, by being power efficient, having large transmission ranges while remaining accurate and minimizing the cost of the system as much as possible. Once we made sure the board and sensors are compatible and execute the way we previously described, we must keep an eye on the battery specifications; the solar panels must generate enough power for each node to sustain itself for a long while. Therefore, we should calculate and analyze the power produced by the solar panel we will be using and compare it to the power consumed by each node during data collection and transmission.

After thorough study of the requirements mentioned above, we will order our hardware components and work on the software and machine learning algorithm while we await the shipment.

The next step is the testing part. It is best to start by testing hardware alone of course to make sure that it is properly working and that we do not have any problems with connections and component defects. Further on, we shall assemble the hardware and software and check the accuracy of our design's output, by comparing it to available data that we have found. Therefore, we can make assessments on the efficacy of our work.

When it comes to the irrigation decision making system, research did not provide any formula or precise technique, however we found certain limits and boundaries of desired conditions depending on the soil type [11]. Therefore, we will use machine learning in order to analyze the collected data and build our own model. Needing a large year-round dataset to build a model, and not finding any online, we were limited to unsupervised machine learning techniques that require small data and adapt. For the previous reasons, we will be using online learning in the form of reinforcement learning to adjust the watering amount, offering the system a reward every time it approaches the desired output, measured after each irrigation. This will allow us to adapt to changing conditions, while personalizing the irrigation of each sector and collecting data to better model the system.

Finally, we need to provide the farmer with an interface to view the collected data in an easy, convenient and simple way. The most adequate way is through a web interface that can be accessed by any devise on the farm. The web interface should allow the farmer to add sectors, specifying their size, soil type and crop type, and should display the readings in tables and graphs to better visualize them.

9 Design

9.1 Design Alternatives and Decisions

In order to make the best choices with regards to hardware components and software tools, we considered alternatives for the sensors used, board, and communication method. Therefore, we setup multiple designs showcased bellow.

9.1.1 Alternatives and Decision for Overall Design

9.1.1.1 Alternatives for the network topology

To connect the wireless sensor network, two network topologies are possible:

- Point-to-point: point-to-point permits the data to hop from a node to another without passing through a central node
- Mesh Network: mesh topology can offer numerous repeated paths for the communication process

In terms of its capabilities in networking, ZigBee offers a diverse set of network topologies: point-to-point topology, star topology and mesh topology. In particular, the mesh network topology tends to be fit for large-area and dynamic networks, because nodes are at a significant distance from one another and in order for them to communicate they require multi-hop transmissions. In addition to that, there exists lots of interference in the communication links, making nodes considered "active"/"inactive" periodically in the network. Given all these various applications used for wireless mesh networking, it seems that this topology is most adequate for our needs in this project

9.1.1.2 Alternatives for the parameters measured

In order to make a precise decision on whether to irrigate or not, we had to choose amongst a variety of parameters, such as the geographic location (Altitude), atmospheric pressure, exposure to light and many others. For practicality, simplicity and cost we will be measuring the air temperature and humidity, in addition to the soil moisture and temperature [28]. Although it is important to note that our project is scalable, and changes can easily be made in order to accommodate for new type of data.

9.1.1.3 Alternatives and Decision for the sensors used

In our design, we will be using three different sensors. An air temperature and humidity sensor, a soil moisture sensor and a soil temperature sensor. Many options are available in the market, therefore we needed to setup criteria in order to choose the most suitable one for our design. The criteria chosen were the voltage needed, accuracy, the range and the cost. The comparison results are shown in the table.

	Sensor	Supply Voltage	Accuracy (°C)	Min t (°C)	Max t (°C)	Cost
Temperature	LM77CIMM-3 [12]	3 - 5.5	1.5	-55	125	1.84$
	AD22105ARZ [13]	2.7 - 7	0.5	-40	150	3.25$
	MCP9700 [13]	2.3 - 5.5	-4 / 6	-40	150	0.37$
Temperature and Humidity	RHT03 [14]	3 - 3.6	0.5	-40	80	9.95$
	DHT22 [15]	3-5V	0.5	-40	125	5$
	DHT11 [15]	3-5V	2	0	50	5$
Soil Moisture	SEN0114 [16]	3.3 - 5	2%			5.95$
	VH400 [17]	3.3 - 20	2%	-40	85	37.95$

Table 1: Sensor Comparison

Final Decision

From the results shown in the table above, we conclude that, according to our chosen criteria, the most suitable sensors were the DHT11 for the air humidity and temperature and the

SEN0114 for the soil moisture and for the soil temperature we will use the K type temperature sensor.

9.1.2 Alternatives and Decision for the Zigbee modules used

Having chosen Zigbee as our communication protocol, adopting a mesh network, we are presented with two alternatives that fit our requirements, and are available to us, the Zigbee XBee S2 and Zigbee XBee Pro S2.

9.1.2.1 Zigbee XBee S2 Specifications

- Price $54.5
- 3.3V @ 40mA
- 250kbps Max data rate
- 2mW output (+3dBm)
- 400ft (120m) range
- U.FL antenna connector
- 6 10-bit ADC input pins
- 8 digital IO pins
- 128-bit encryption
- Local or over-air configuration
- AT or API command set

9.1.2.2 Zigbee XBee Pro S2 Specifications

- Price $81.75
- 3.3V @ 215mA
- 250kbps Max data rate
- 63mW output (+18dBm)
- 2 miles (3200 m) range
- U.FL antenna connector
- 6 10-bit ADC input pins
- 8 digital IO pins
- 128-bit encryption
- Local or over-air configuration
- AT or API command set

Both units having similar characteristics, differing on range, power consumption and output power, which makes sense, since the pro version covers a longer range, it outputs a higher power, thus needs to consume more power.

In our application, we'd like to have a refined segmentation of the planted field, therefore do not need the extra range provided by the Pro unit. In addition, power efficiency being a major factor, the choice is clearly the Zigbee XBee S2 unit.

9.1.3 Alternatives and Decision for the main board

When picking the board to use to connect the sensors and transmitter unit, we had two choices, either print a custom-made board, or use a ready-made board.

After our research into the needed boards, due to the form factor, ease of use and to time constraints, we chose to use a ready-made board available at AUB: The Arduino UNO.

9.2 Design Iterations

In order to make the best choices with regards to hardware components and software tools, we considered alternatives for the sensors used, board, and communication method. Therefore, we setup multiple design Iterations showcased bellow.

9.2.1.1 Board Design iteration

Fin bellow a table comparing the different ready-made board we found. [18]

	Arduino Mega 2560	Libellium	Greenmote	Arduino UNO	Arduino Due
Microcontroller	AT mega2560	ATmega1281	MSP430f5437A	Atmega 328	AT91SAM3X8E
Memory	8K RAM 256K Flash memory	SRAM 8KB EEPROM 4KB Flash 128KB	RAM 16KB ROM 256 KB FRAM 4Kbit	SRAM 2KB Flash memory 32KB EEPROM 1KB	SRAM 96KB Flash memory 512KB
Analog I/O	16	7	No analog input	6/0	12/2
Digital I/O	54	8		14/6	54/12
Power supply	Solar cell Voltage 12V Power 10W Long battery lifetime	Solar pannel Voltage 3.3V-42V Lifetime 1 year	Low power Voltage 3V-36V	Voltage 7-12V	Voltage 7-12V
Software	Int. Dev. Env. Of Arduino / C-C++	Java	Java	Int. Dev. Env. Of Arduino / C-C++	Int. Dev. Env. Of Arduino / C-C++
Sensors	Temperature Light intensity soil moisture	Temperature Accelerometer	Temperature Humidity Visible light sensor	Different sensors depending on needs	Different sensors depending on needs
Cost	150 EURO	250 $	200$	29$	39$

Table 2: Board Comparison table

In addition, as we mentioned earlier, we considered printing a custom board. After looking deeper into each board, we found that some do not meet our needs for processing, Zigbee compatibility, and cost effectiveness. Hence, our choice was limited to either a custom Board or an Arduino UNO. Finally, due to bulkiness and overall cost, a custom board was out of the question, making our board of choice the Arduino UNO.

10 Preliminary Implementation and Testing

10.1 Preliminary Implementation

Before Implementing the system, we had to test each ordered part individually to see if they were working or not. After testing, and making sure each component worked, separately, we assemble the components forming each node, and the base station.

Our first network will consist of three identical nodes and a base station made up of a laptop. Each node consists of an Arduino UNO board, a ZigBee shield and ZigBee XBee S2 transmitter, in addition to the sensors used to collect data: soil moisture sensor, and air temperature and humidity sensor, both Arduino compatible. The base station is a ZigBee transmitter connected to a laptop through an adaptor, using the Arduino software for interpretation.

10.1.1 Implementing Zigbee

In Zigbee, there are three different device types to which a Zigbee chip can be configured:

- Coordinator: "allow routers and end devices to join the PAN, transmit and receive RF data transmission, and route the data through the mesh network." [19]
- Router - "Transmit and receive RF data transmission, and route data packets through the network." [19]

- End Device - "Cannot assist in routing the data transmission but transmit or receive RF data transmission, and intended to be battery-powered devices." [19]

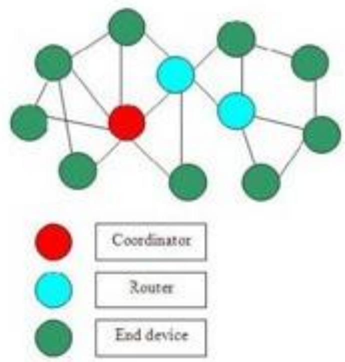


Figure 4: Mesh Network

In a mesh network topology, we usually have a coordinator, a couple of routers and end devices. The routers can be linked to other routers or end devices. There are no strict communication rules for the mesh network topology. It is indeed flexible since the routers that are in range of each other can communicate. "An advantage of mesh network is that there is likely another alternative route in case an existing link fails. Hence, this type of network topology is very reliable." [19]

Steps that were followed to configure the network and the chips

Our experiment's network consists of 4 Zigbee chips: a coordinator (our base station), two routers and an end device.

First, we installed a software called x-ctu that allows us to configure the Zigbee chips. After that, we connect the ZigBee chip to the PC using a serial-to-USB adapter. We then read the chip and change its type to API Coordinator and set a unique PAN ID and a channel, both of which will be the same for all the other ZigBee chips. We set the DH, being the destination (High) to 0, and the DL (Low) to FFFF.

After that the two chips that are to be routers are configured as Router API, and we enter in the PAN ID and Channel fields the same as the coordinator's. We set the DH and DL to 0, making the routers always route the data received to the coordinator.

Finally, the chip that will be the end device is plugged, and we change its type to END-Device API, set its PAN ID and Channel fields to the same as the coordinator's and set the DH and DL to 0.

10.1.2 Implementing the Sensors

After choosing the sensors comes the connection of theses sensors to the Arduino. The connection was a relatively easy task since the sensors were all Arduino compatible. Starting with the air temperature and humidity sensor (DHT11), the latter was connected as shown in the figure below.

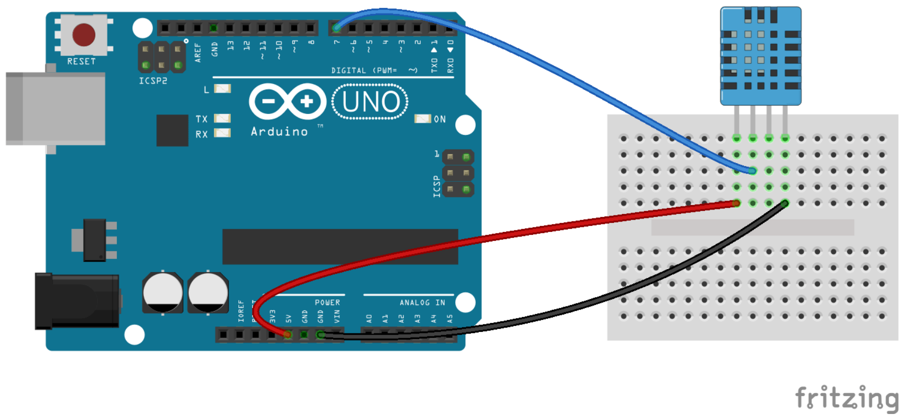
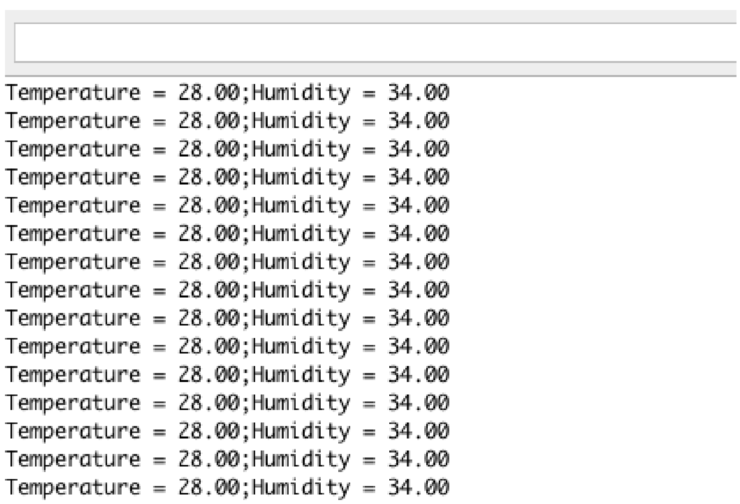


Figure 5: Arduino UNO connected to a DHT11 sensor

"from http://www.hobbyist.co.nz/?q=documentations/wiring-up-dht11-temp-humidity-sensor-to-your-arduino"

The sensor was tested and gave the results showed in the snapshot below.



```
Temperature = 28.00;Humidity = 34.00
Temperature = 28.00;Humidity = 34.00
Temperature = 28.00;Humidity = 34.00
Temperature = 28.00;Humidity = 34.00
Temperature = 28.00;Humidity = 34.00
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Temperature = 28.00;Humidity = 34.00
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Figure 6: Temperature and humidity readings

As shown in the snapshot, everything seems to be working as expected.

Second, we come to the soil moisture sensor. Also, this sensor is Arduino compatible and therefore was easy to connect, as shown in the figure below

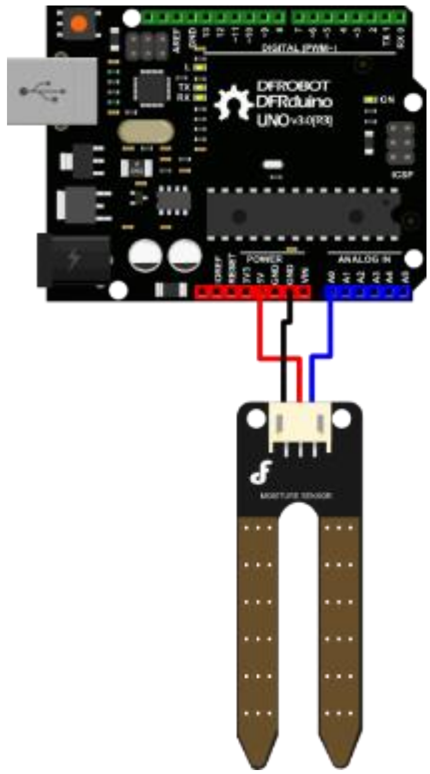


Figure 7: Arduino connected to a soil Moisture Sensor

from https://www.dfrobot.com/wiki/index.php/Moisture_Sensor_(SKU:SEN0114)

After connecting the sensor to the Arduino, we can monitor the values outputted from the sensor from the serial monitor of the Arduino software. The output ranges from 0 to values larger than 700, and in terms of voltage from 0V-4.2V. outputs less than 300 correspond to extremely dry conditions, between 300 and 700 are nominal conditions and greater than 700 are very wet conditions [https://www.dfrobot.com/index.php?route=product/product&product_id=599#.U1PLxqLiO2Y].

The snapshot below shows a small demonstration of what can be outputted by the moisture sensor.

Figure 8: Moisture Readings

10.1.3 Packaging

The nodes having to be put in a field and plugged into the soil, they need to be protected from elements such as heavy rain and wind. In order to protect our unit and ensure effectiveness and consistency in harsh weather conditions, we decided to incase the sensors along with the Arduino boards in a Plexiglas packaging that we built in the labs at AUB. The casing is an airtight, 5.5x10x12 cm^3 in dimension packaging with sensors sticking out of it. It is built in a stable way and can be plugged into the soil in a rather simple way.

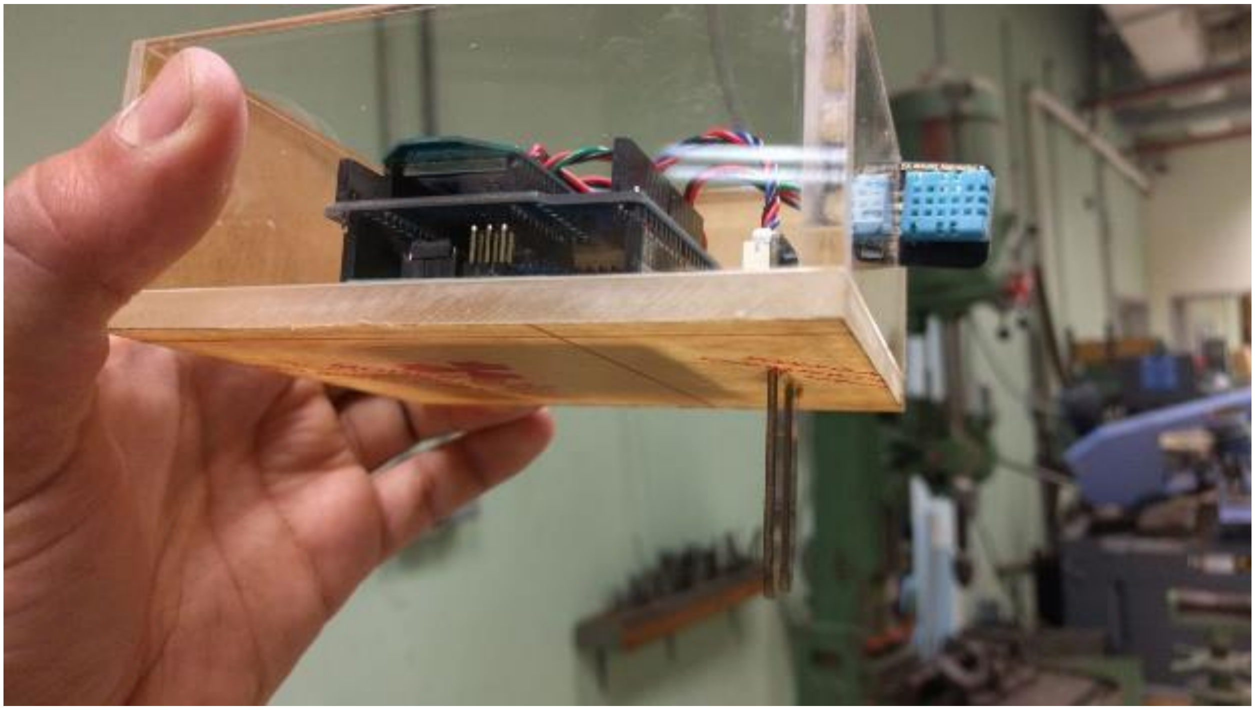


Figure 9: Plexiglas Casing

10.1.4 Interface

10.1.4.1 System Overview

The interface is an example of the developed smart precision agriculture system management interface. A website allows the display of collected field information in a simple and informative way, and management of the irrigation system, and field water usage. The website provides diverse functionalities to its users, as described in the sections below, and is compatible with any web browser on any hardware platform.

10.1.4.2 System Configuration

The system operates using the Hypertext Preprocessor (PHP) engine. It is compatible with every platform or operating system with an active internet connection and a functional web browser. The system requires the latter in order to save the acquire weather data.

For simplicity, security and reliability purposes, the database is hosted on the user's machine using wamp server with the required databases created.

10.1.4.3 User Access Levels

The main page of the website can be publicly accessed by everyone. Although, in order to benefit from its functionalities, you have to be a registered member and have the system and at least one node installed.

10.1.4.4 Contingencies

In case the user has no active internet connection, then there will be no access to the weather server and, subsequently, will be limited to the local data. The system will function normally.

10.1.4.5 Use Cases

The Main Page of the Website is used for advertisement and to attract new customers, and in order to keep active members up-to-date to our news and updates. In addition, it contains our contact information for perspective customers to contact us for inquiries. As well as having the login portal for the current customers to access their field's data.

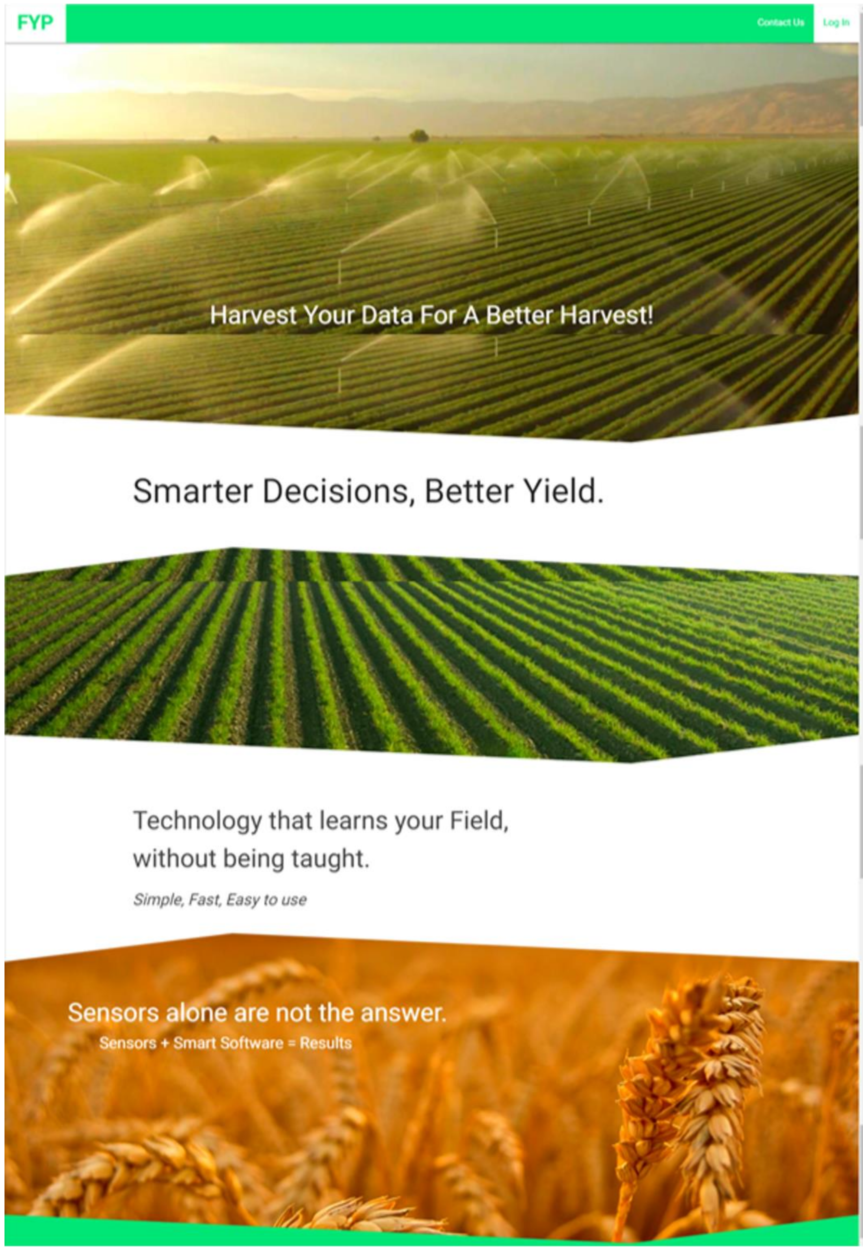


Figure 10: Website Main Page

When a new customer decides to sign up, they press on Log In, then on Register Now, in order to fill in their name, username, password and email, in order to build a simple profile. The Password is hashed and stored encrypted in the database user table. After a successful register, the user is prompt to fill in the rest of his personal information.

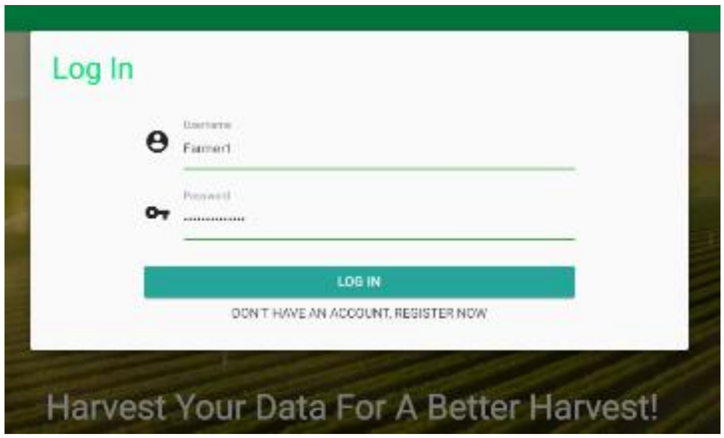


Figure 11: Log In Page

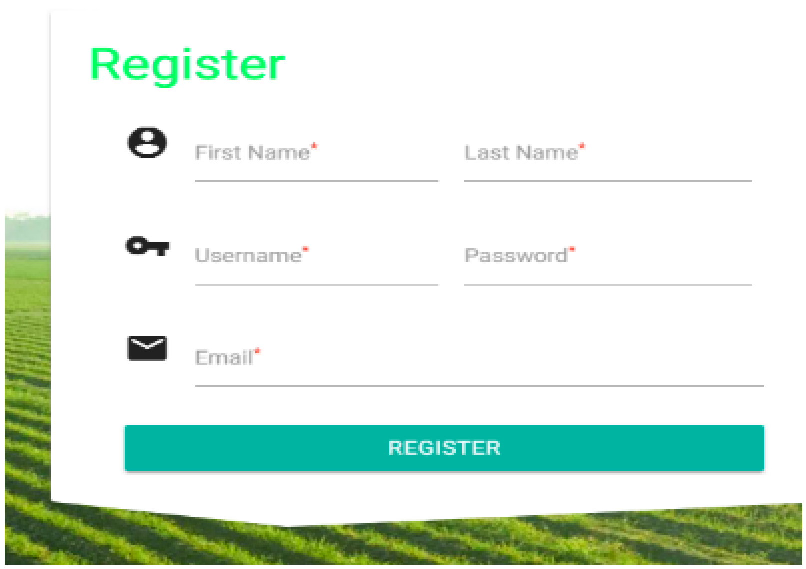


Figure 12: Registration Page

Once logged In, the farmer should add at least one Sector, specifying a unique name for the sector, the size of the sector, a small description of the sector, in addition to the type of crop planted and the type of soil of that sector. The farmer can add as many sectors as he'd like, no size limitation is imposed.

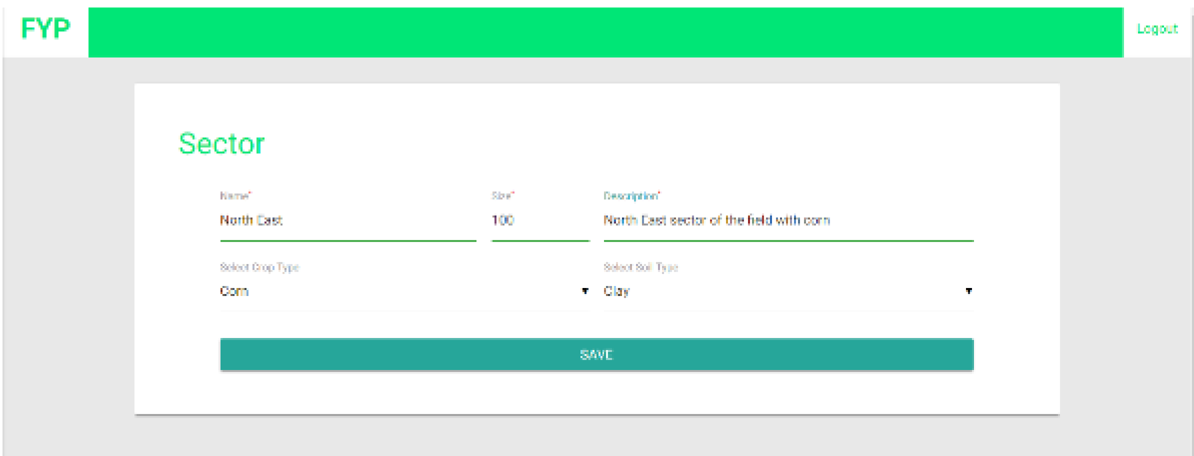


Figure 13: Sector add/edit Page

The sector size, crop type and soil type allow us to calculate a rough estimate of the sector's water needs. This rough estimate is used as our preliminary estimate for our decision-making algorithm.

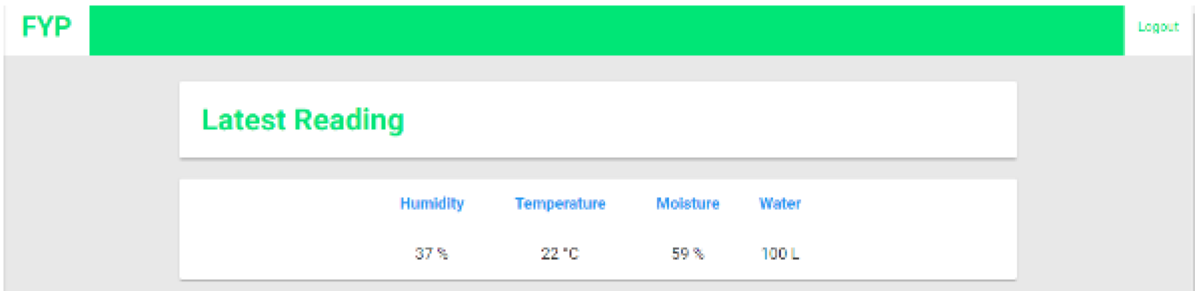


Figure 14: Last Reading Page

At steady state, the farmer's homepage displays the average Humidity, temperature and moisture of all his sectors, essentially his full field.

The 10 latest readings are displayed in a table, with individual graphs for temperature, humidity and moisture. In addition, a pie chart sections the moisture readings into five categories, to better explain the water volume in the soil:

- Extreme Stress
- Stress
- Optimal
- Excess
- Extreme Excess

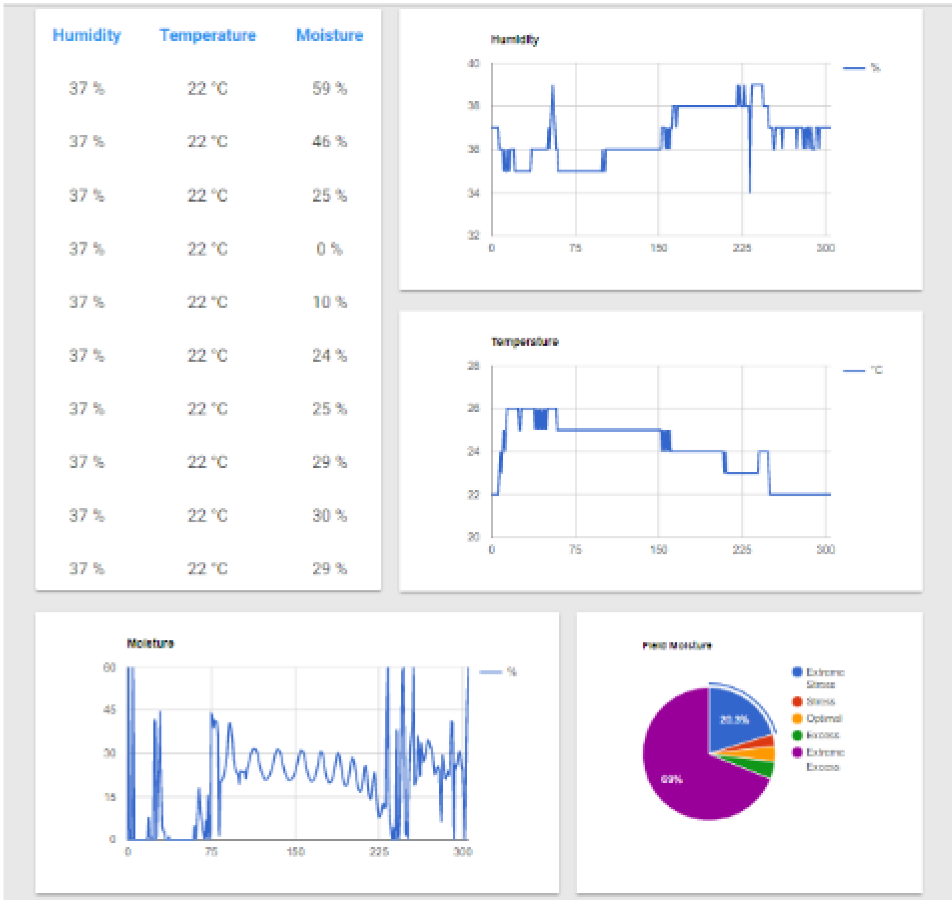


Figure 15: Field Dashboard

10.1.5 Decision Making Algorithm

As discussed in our solution methodology, our decision-making algorithm is categorized as online learning, meaning the model keeps changing with every reading, the online learning approach we found to be best is reinforcement learning, setting our goal to be staying in the Optimal moisture zone, and rewarding each modification that keeps us in this optimal zone, and punishing modifications that over or under irrigate a sector.

We used this approach because a large enough dataset to train traditional machine learning algorithms, and artificial neural networks. The implemented form of machine learning allows us to tend to each sector's need individually, while building a dataset to possibly test more machine learning algorithms in the future.

In order to avoid a very steep learning curve, we used our research and available data about the sector to estimate an adequate starting point, using sector size, soil type and crop type. The interface's computing being written in PHP, we found it an adequate language to implement our decision-making scheme, using a database to store each sector's reward history.

10.2 Testing

When implementing on the small scale, due to budget limitations and items availability, we will be using three sensors, of which a temperature sensor, a humidity sensor and a soil moisture sensor. In addition to that, the experiment to test our system will not be using solar energy to sustain our unit, although, as we’ve seen previously, solar power can easily and consistently power our unit. Instead, we will be using a regular 9V battery that can power our unit for as long as a whole year before needing replacement.

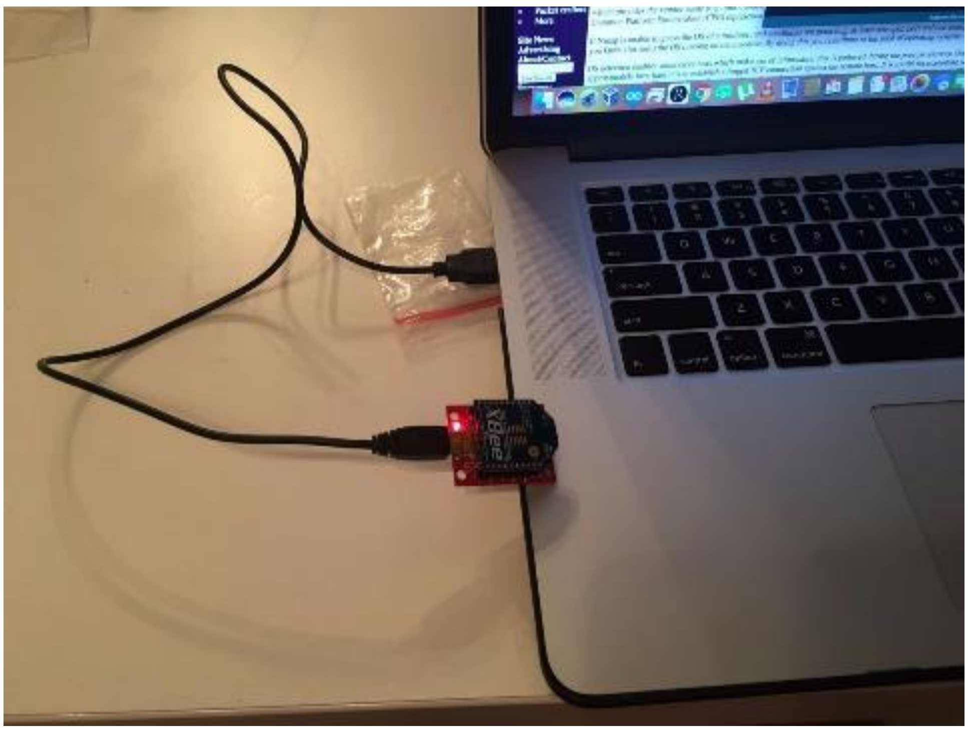


Figure 16: Base Station - Laptop and ZigBee Receiver

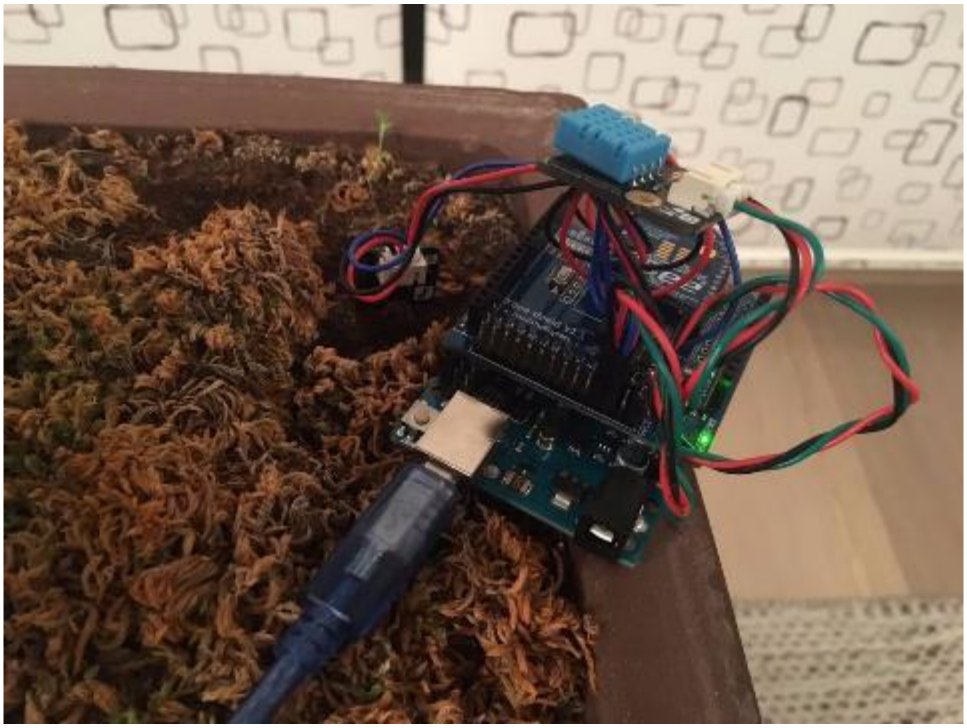


Figure 17: Sensor Node without Housing

In regards to our unit's resistance to water pressure from rain, hail, snow and relatively high wind speeds, it seems that we do not have any problems as the packaging for the unit is able to endure relatively harsh weather conditions.

In order to collect data from the sensors and to feed the data to the machine learning algorithm implemented, we plugged the unit into a plant in one of our homes and had the sensors collect data for temperature, humidity and soil moisture. The unit then sent that data wirelessly through Zigbee protocol to the base station, which is a laptop that we kept running to record the data. The data is printed on the serial of the Arduino and collected from the computer using a software called processing and store it in a text file. Processing uses java as a language and using libraries it can interface with the Arduino in order to copy the data from the serial of the Arduino. Afterwards, the web interface detects the updates to the text file and uploads them to the database. The values now in the database, we showcase graphs and statistics, as well as process this data and feed it to the machine learning algorithm. One of the pre-processing steps involves transforming the moisture readings into actual percentages.

Once that our machine learning algorithm has been trained to the set of data we fed it, we orchestrated a final test, which is our final experiment, where we have the unit collect data using the sensors, transmit it to the base station using Zigbee protocol, store the values collected into our database, and have the machine learning algorithm process the data in order to come up with a decision that specifies how much water will be used to irrigate the plant.

11 List of Resources and Engineering Tools Needed

11.1 Resources

Since the project requires having a hardware design, we will need to order the different components that make up our system:

11.1.1 Zigbee Transmitter/Receiver:

Name: “XBee Series 2” [20]

Price: $54.5

Description: “This is the very popular 2.4GHz XBee module from Digi. These modules take the 802.15.4 stack (the basis for Zigbee) and wrap it into a simple to use serial command set. These modules allow very reliable and simple communication between microcontrollers, computers, systems, really anything with a serial port. Point to point and multi-point networks are supported.” [20]

Specs:

- “3.3V @ 40mA
- 2mW output (+3dBm)
- 400ft (120m) range
- 00ft (100m) range
- Fully FCC certified
- 6 10-bit ADC input pins
- 8 digital IO pins
- 128-bit encryption
- Local or over-air configuration
- AT or API command set
- Trace Antenna” [20]

11.1.2 Soil Temperature Sensor:

Name: “109-SSL Stainless Steel Temperature Probe for Harsh Environments” [21]

Price: N/A

Description: “The 109SS is a rugged, accurate probe that measures soil or water temperature from -40° to +70°C. It is especially suited for harsh, corrosive environments, and can be easily interfaced with data-loggers.” [21]

Features:

- “Designed for harsh, corrosive environments
- Fast response time
- Wide temperature measurement range
- Easy to install or remove
- Compatible with the CWS900-series interfaces, allowing it to be used in a wireless sensor network” [21]

11.1.3 Air Humidity and Temperature Sensor:

Name: “Humidity and Temperature Sensor – RHT03” [22]

Price: $9.95

Description: “The RHT03 (also known by DHT-22) is a low-cost humidity and temperature sensor with a single wire digital interface. The sensor is calibrated and doesn’t require extra components so you can get right to measuring relative humidity and temperature.” [22]

Features:

- “3.3-6V Input
- 1-1.5mA measuring current
- 40-50 uA standby current
- Humidity from 0-100% RH
- -40 - 80 degrees C temperature range
- +-2% RH accuracy
- +-0.5 degrees C” [22]

11.1.4 Soil Moisture Sensor:

Name: “SparkFun Soil Moisture Sensor” [23]

Price: $4.95

Description: “The SparkFun Soil Moisture Sensor is a simple breakout for measuring the moisture in soil and similar materials. The soil moisture sensor is pretty straight forward to use. The two large exposed pads function as probes for the sensor, together acting as a variable resistor. The more water that is in the soil means the better the conductivity between the pads will be and will result in a lower resistance, and a higher SIG out.” [23]

11.1.5 Soil Acidity/pH Sensor:

Name: Tris-Compatible Flat PH Sensor [24]

Price: $135 (Price makes this device questionable since it might be too expensive, but it seems to be the only one that fits our needs, since almost all other PH sensors output the PH on a screen only)

Description: “The Tris-Compatible Flat pH Sensor is a highly versatile sensor. Because the glass membrane is flat instead of a bulb, it is more durable, easier to clean, and allows for flat surface measurements or smaller sample sizes. It features a sealed, gel-filled, double-junction electrode, making it compatible with Tris buffers and solutions containing proteins or sulfides. The flat glass shape also makes it useful for measuring the pH of semisolids such as food or soil slurries.” [24]

Features:

- “Range: pH 0–14 (Some sodium error in ranges greater than pH 12 due to thicker glass and higher impedance values)
- Electrode type: Double-junction, sealed, gel-filled, Ag/AgCl reference, polycarbonate body
- Membrane style: Flat glass
- Storage solution: pH 4/KCl solution (10 g KCl in 100 mL buffer pH-4 solution)
- Cable: 1-meter coaxial cable with BNC connector
- Temperature range: 0– 100ºC
- 12 mm OD
- Impedance: ~20 kΩ at 25ºC
- Response time: 98% of full response in 30 s at 25ºC” [24]

11.1.6 Soil Electrical Conductivity:

Name: Non-Contact EC sensor [25]

Price: N/A

Description: “Non-contact EC sensors work on the principle of electromagnetic induction (EMI). EMI does not contact the soil surface directly. The instrument is composed of a transmitter and a receiver coil, usually installed at opposite ends of the unit. A sensor in the device measures the resulting electromagnetic field that the current induces. The strength of this secondary electromagnetic field is proportional to the soil EC. These devices, which directly measure the voltage drop between a source and a sensor electrode, must be mounted on a non-metallic cart to prevent interference. These sensors are lightweight and can be handled easily by a single individual, thus making them useful for small areas.” [25]

11.1.7 4G LTE Dongle:

Name: E3276s [26]

Price: $87

Description: A device that you plug in using USB 2.0 or 3.0 ports that provides the user with access to the internet

Features:

- “Speed: 150Mbps

- Installation: Plug and Play (Auto-Installation)
- Network Compatibility: LTE, DC-HSPA+, HSPA+, HSPDA, UMTS, EDGE, GPRS, GSM." [26]

11.2 Engineering Tools Needed

The Precision agriculture system is made up of both hardware and software, therefor the needed tools are as follows.

11.2.1 Hardware Tools Needed

In order to Build our System, we need to construct individual nodes and a base station. We will need the following hardware related tools:

· **Soldering:** Each node is made up of sensors that we have to solder into a board.

· **Solar battery charging system:** In order to have a self-sustaining system we need to be able to recharge the batteries without damaging them.

11.2.2 Software Tools Needed

For the system to function properly we will need to program it using the following tools:

· **Zigbee Network Setup Tool:** We need to learn how to setup a Zigbee mesh network.

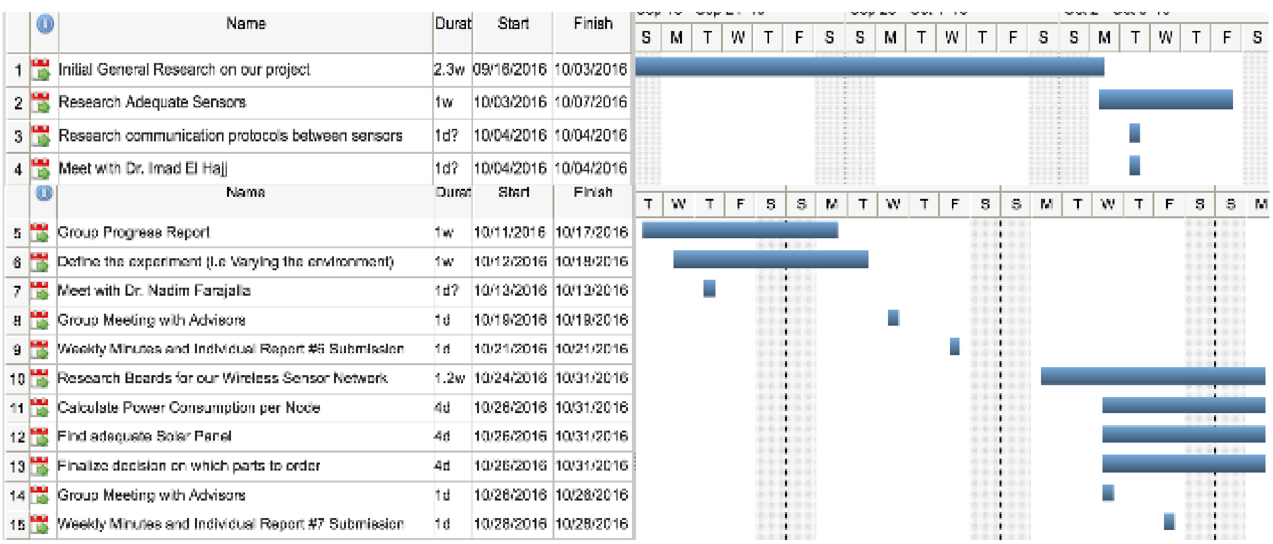
· **Server communication Language:** In order to push data to the database we will have to use mySQL.

· **Server Scripting language:** In order to communicate with the Sever, we need to use PHP.

· **Machine Learning Oriented Language:** To be able to have a smart system that adjusts itself we must learn how to use Matlab or R for machine learning.

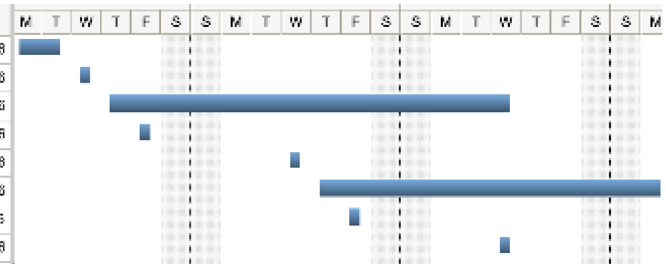
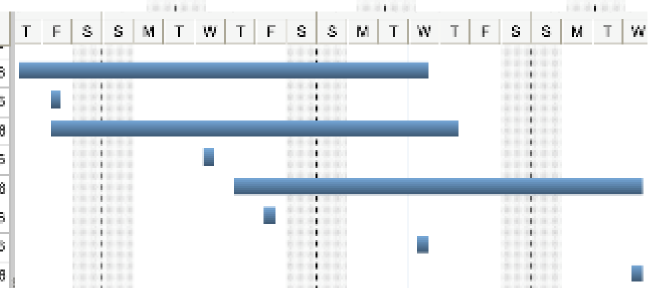
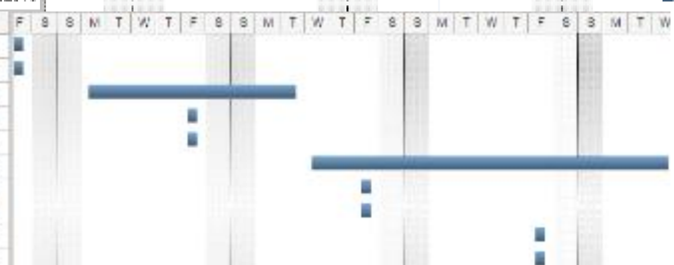
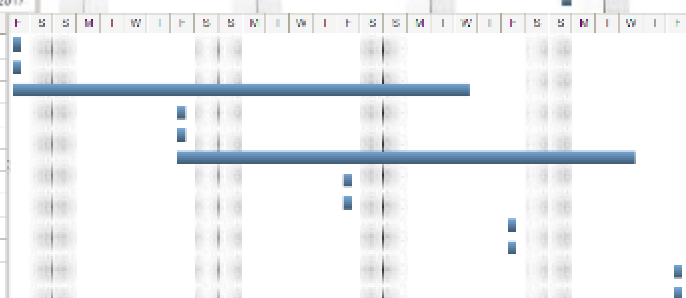
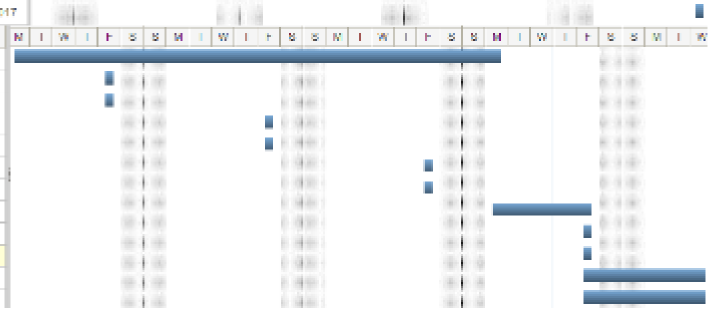
· **Web languages:** The web interface being the primary data display and overwrite method for the farmer, we need to use HTML, CSS, and JAVASCRIPT.

12 Detailed Project Schedule



	Name	Durat	Start	Finish
1	Initial General Research on our project	2.3w	09/16/2016	10/03/2016
2	Research Adequate Sensors	1w	10/03/2016	10/07/2016
3	Research communication protocols between sensors	1d?	10/04/2016	10/04/2016
4	Meet with Dr. Imad El Hajj	1d?	10/04/2016	10/04/2016
	Name	Durat	Start	Finish
5	Group Progress Report	1w	10/11/2016	10/17/2016
6	Define the experiment (I.e Varying the environment)	1w	10/12/2016	10/18/2016
7	Meet with Dr. Nadim Farajalla	1d?	10/13/2016	10/13/2016
8	Group Meeting with Advisors	1d	10/19/2016	10/19/2016
9	Weekly Minutes and Individual Report #6 Submission	1d	10/21/2016	10/21/2016
10	Research Boards for our Wireless Sensor Network	1.2w	10/24/2016	10/31/2016
11	Calculate Power Consumption per Node	4d	10/26/2016	10/31/2016
12	Find adequate Solar Panel	4d	10/26/2016	10/31/2016
13	Finalize decision on which parts to order	4d	10/26/2016	10/31/2016
14	Group Meeting with Advisors	1d	10/26/2016	10/26/2016
15	Weekly Minutes and Individual Report #7 Submission	1d	10/28/2016	10/28/2016

	Name	Durat	Start	Finish
16	Order all needed Parts	2d	10/31/2016	11/01/2016
17	Group Meeting with Advisors	1d	11/02/2016	11/02/2016
18	Setting up the wireless sensor network	2w	11/03/2016	11/16/2016
19	Weekly Minutes and Individual Report #8 Submission	1d	11/04/2016	11/04/2016
20	Group Meeting with Advisors	1d	11/09/2016	11/09/2016
21	Design details and finalization	1.6w	11/10/2016	11/21/2016
22	Weekly Minutes and Individual Report #9 Submission	1d	11/11/2016	11/11/2016
23	Group Meeting with Advisors	1d	11/16/2016	11/16/2016
24	Build design and start testing	2w	11/17/2016	11/30/2016
25	Weekly Minutes and Individual Report #10 Submission	1d	11/18/2016	11/18/2016
26	Group Final Report Submission	2w	11/18/2016	12/01/2016
27	Group Meeting with Advisors	1d	11/23/2016	11/23/2016
28	Group Final Report Presentation	2w	11/24/2016	12/07/2016
29	Weekly Minutes and Individual Report #11 Submission	1d	11/25/2016	11/25/2016
30	Group Meeting with Advisors	1d	11/30/2016	11/30/2016
31	Log Book Submission	1d	12/07/2016	12/07/2016
32	Group Meeting with Advisors	1d?	02/03/2017	02/03/2017
33	Weekly Minutes and Individual Report #12 Submission	1d?	02/03/2017	02/03/2017
34	Packaging	7d?	02/08/2017	02/14/2017
35	Group Meeting with Advisors	1d?	02/10/2017	02/10/2017
36	Weekly Minutes and Individual Report #13 Submission	1d?	02/10/2017	02/10/2017
37	Data Collection	11d?	02/15/2017	03/01/2017
38	Group Meeting with Advisors	1d?	02/17/2017	02/17/2017
39	Weekly Minutes and Individual Report #14 Submission	1d?	02/17/2017	02/17/2017
40	Group Meeting with Advisors	1d?	02/24/2017	02/24/2017
41	Weekly Minutes and Individual Report #15 Submission	1d?	02/24/2017	02/24/2017
42	Group Meeting with Advisors	1d?	03/03/2017	03/03/2017
43	Weekly Minutes and Individual Report #16 Submission	1d?	03/03/2017	03/03/2017
44	Create website and store data	14d?	03/03/2017	03/22/2017
45	Group Meeting with Advisors	1d?	03/10/2017	03/10/2017
46	Weekly Minutes and Individual Report #17 Submission	1d?	03/10/2017	03/10/2017
47	Feed Machine Learning	14d?	03/10/2017	03/29/2017
48	Group Meeting with Advisors	1d?	03/17/2017	03/17/2017
49	Weekly Minutes and Individual Report #18 Submission	1d?	03/17/2017	03/17/2017
50	Group Meeting with Advisors	1d?	03/24/2017	03/24/2017
51	Weekly Minutes and Individual Report #19 Submission	1d?	03/24/2017	03/24/2017
52	Group Meeting with Advisors	1d?	03/31/2017	03/31/2017
53	Weekly Minutes and Individual Report #20 Submission	1d?	03/31/2017	03/31/2017
54	Final Testing	16d?	04/03/2017	04/24/2017
55	Group Meeting with Advisors	1d?	04/07/2017	04/07/2017
56	Weekly Minutes and Individual Report #21 Submission	1d?	04/07/2017	04/07/2017
57	Group Meeting with Advisors	1d?	04/14/2017	04/14/2017
58	Weekly Minutes and Individual Report #22 Submission	1d?	04/14/2017	04/14/2017
59	Group Meeting with Advisors	1d?	04/21/2017	04/21/2017
60	Weekly Minutes and Individual Report #23 Submission	1d?	04/21/2017	04/21/2017
61	Final Project Report	5d?	04/24/2017	04/28/2017
62	Logbook Submission	1d?	04/28/2017	04/28/2017
63	Weekly Minutes and Individual Report #24 Submission	1d?	04/28/2017	04/28/2017
64	Poster Preparation and submission	4d?	04/28/2017	05/03/2017
65	Final Presentation	4d?	04/28/2017	05/03/2017

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14 Appendix

14.1 Updated Project Description and Agreement Form

Faculty Supervisor	**Mazen Saghir**
Co-Supervisor [optional]	Haitham Akkary
Sponsor [optional] *Is there industry support or funding the project?*	None
Project Title *Descriptive title* *not necessarily the final title that will be adopted by the team*	Optimized Precision Agriculture using Machine Learning
Project Description and Design Aspects *What is the main motivation for the project?* *Specify the desired needs that the final product is expected to meet.*	Motivation: Agriculture is the most important consumer of water, where it consumes around 70% of world's fresh water, and fresh water is becoming a scarce resource, therefore improving the irrigation system of this industry will have a major impact on the overall water consumption.

	Desired Needs: A self-sustaining, automated irrigation method that adapts to crop need and environment conditions.
Expected Deliverables	1. A node made up of the data collection sensors, processor and transmitter. 2. A base station that collects the data and forwards it to a server, storing it in its database and making it visible on a website. 3. A machine learning algorithm that controls irrigation given the sensor data.
Technical Constraints	1. Power consumption must be as little as possible in order to reduce cost as well as increase efficiency (Solution: The system will be using solar energy that will be stored in batteries, making the system self-sufficient). 2. A rechargeable battery should be used in order to power the nodes. 3. The required sensors' input voltages should match with the voltage on the board used for each node.

	4. The Size of the sensor should be relatively small in order for it not to interfere and not to be an obstacle to the farmers' movement in the field (Thus, a design for the sensor with a $30x30x20cm^3$ should be enough to fit all the components that are needed). 5. The system should be precise in a sense that it will have an output that is reliable, meaning the output should not have variations of more than 5% for the same input. 6. The irrigation system that the client has already deployed should be divided into multiple regions in order to have the ability to control the irrigation in specific regions. 7. Sensors must be able to form a sensor network communicating with a central node. 8. Remote Access to the network must be available.

Non-Technical Constraints	1. The design must come at a rational cost, it must therefore be affordable for clients and farmers that own relatively small lands. 2. The nodes in our Wireless Sensor Network must not contain any kind of material that could be dangerous or toxic for the crops' soil or plants. 3. The nodes in our Wireless Sensor Network must be wrapped in a way that is appropriate for a wet and muddy environment as well as harsh weather conditions. 4. We should avoid wirings as much as possible. 5. The sensors should have low energy consumption rates 6. The maintenance required for the power supply (solar panels and battery storage) should be easy to do and non-frequent (at least a year before a maintenance check-up). 7. The network's security must be complex and reassuring to the clients, since getting access to the network good to a lot of damage. For instance, a hacker could flood the crops or steal private data from the server, raising an issue of privacy for the client/farmer. 8. The user interface should be simple and easy to use in order for the farmers to adopt such systems, otherwise they will show lack of interest in a complex system and will most

	likely stick to their current system since they are familiar with it.
Contemporary Issues	"Looking at last year, he said, better uses of data analysis have raised his return on investment to 21.2 percent, from 14 percent. Other technology, like variable rates of irrigation and automated farm machinery, he said, accounted for another 4 percent of the total." The New York Times – Working the land and the data
Resources and Engineering Tools	• Zigbee Transmitter/Receiver: • Soil Temperature Sensor:

Identify resources and engineering tools needed and whether they are available or need to be acquired (if known), e.g. software licenses, instruments, facilities, components, …	• Air Humidity and Temperature Sensor: • Soil Moisture Sensor: • Soil Acidity/pH Sensor: • Soil Electrical Conductivity: • 4G LTE Dongle: • Soldering tools • Solar battery charging system • Zigbee Network Setup Tool • Server communication Language • Server Scripting language • Machine Learning Oriented Language • Web languages
Possible Applicable Standards *List potential standards directly or indirectly used or involved in the project*	1. ANSI Y10.5-1968: The ANSI Letter Symbols for Quantities. 2. ASCII-1967: The American Standard Code for Information Interchange. 3. IEEE 802.15.4: The IEEE standard for Zigbee, the networking protocol used for signal transfer in this project. 4. IEEE 308.1969: The IEEE Criteria for Class IE Electric Systems. 5. IEEE 802.11a: The IEEE standard for implementing wireless local area network (WLAN) computer

	communication in the 900MHz, 2.4, 3.6, 5 and 60 GHz frequency bands.
List of Disciplines	○ Circuits and Electronics ○ Communications and Networking ○ Control, Robotics, and Instrumentation ○ Hardware, Computer Architecture, and Digital Systems ○ HMI, Graphics, and Visualization ○ Intelligent Systems ○ Machines and Power Systems ○ Signal Processing ○ Software Engineering Additional Non-Engineering discipline(s) (Specify): Agriculture
Number of Students *Please consider the number of disciplines checked above*	3 students
Required Courses [Optional] *List the courses that are essential for the successful execution of the*	1- 2- 3- .

project (especially advanced courses)	
Date Last Updated	17 October 2016

14.2 Minutes of all Meetings Up-to-Date.

Meeting # 1		
Date: 9.16.2016	Time: 3pm to 4pm	Location: AUB
Meeting called by	Group	
Attendees	Alexander Semaan – Johnny Nader – Majd Nasrallah	
Minutes taker	Alexander Semaan	
Agenda Item: Brainstorming.		
Discussion		
We made sure that we understood what the subject aims at, and we talked about a couple of ideas that could help us advance in our thought process		
Conclusions		
We need to narrow down the subject into something more specific.		
Action Items	**Person Responsible**	**Deadline**
Meet with the advisor Dr. Akkary to narrow down the subject	Alexander, Johnny and Majd	Within a week

Meeting #: 2		
Date: 7.6.2011	Time: from 4 to 5	Location: Bechtel 509
Meeting called by	Prof. Haitham Akkary and Prof. Mazen Saghir	
Attendees	Majd Nasrallah/ Johnny Nader/ Alex Semaan/ Prof. Akkary/ Prof. Mazen	
Minutes taker	Alex Semaan	
Agenda Item: Project Requirements		
Discussion		
We started by presenting our research findings from last week: • The variables that are of concern • The technologies that are currently being used		
Conclusions		
• The variables that are going to be under study are humidity, temperature and moisture, and the reason is because they are the variables that we know for sure that can be measured with current technology • The crop in concern will most probably be vineyards because we think it is a very delicate crop that needs		

Action Items	Person Responsible	Deadline
Build a primitive block diagram of the whole system in order to start digging deeper into each section of the project	Johnny Nader Majd Nasrallah Alex Semaan	In 2 weeks

Agenda Item: Deliverable at the end of the semester

Discussion

Alex Semaan asked about what is expected from us to present at the end of the semester. Prof Akkary answered by saying that small scale system: one sensor (what is the minimum system that could test the functionality of everything->sensors to sensors-> to unit-> to server->to phone)

Conclusions

- Build a small-scale prototype of the irrigation system.

Action Items	Person Responsible	Deadline
Build the prototype	Johnny Nader Majd Nasrallah Alex Semaan	Before the end of the semester

Non-Technical constraint

Discussion

One of the non-technical constraints pointed by Prof Akkary were the friendliness of the farmers in concern with technology such as smartphones, internet etc.

Conclusions

Farmers may not be familiar with technology and might be using old phones that will create limitations for our project. Taking in consideration that the wineries are considered developed industries, they should be more or less familiar with technology.

Action Items	Person Responsible	Deadline
Investigate this issue more by interviewing stakeholders	Johnny Nader Majd Nasrallah Alex Semaan	By next meeting

Meeting #3:

Date: 7.6.2011	Time: from 04:00 PM to 05:30 PM	Location: Prof. Akkary's Office
Meeting called by	Group	

Attendees	Prof. Akkary, Prof. Saghir, Johnny Nader, Majd Nasrallah, Alexander Semaan	
Minutes taker	Johnny Nader	
Agenda Item:		
Discussion	**We discussed narrowing down our broad subject**	
We Started the meeting by discussing the broad subject we set up, Smart Home Technologies. Professor Akkary proposed working on an intel funded project regarding enhancing a RISC 5 based processor, discussing it in detail.		
Conclusions	**We ended up picking smart irrigation in precision agriculture**	
Prof. Akkary suggested we get in touch with Prof. Imad el Hajj, having done some research related to our subject, in addition to someone from the agriculture department to view their available techniques, and needs.		

Action Items	Person Responsible	Deadline
Discuss with Prof. Imad and get relevant documents from his research Discuss with a Prof. from the agriculture department Research existing technologies	Alexander Semaan Johnny Nader Majd Nasrallah	9.28.2016

Meeting #: 4		
Date: 7.6.2011	Time: from 4 to 5	Location: Bechtel 509
Meeting called by	Prof. Haitham Akkary and Prof. Mazen Saghir	
Attendees	Majd Nasrallah/ Johnny Nader/ Alex Semaan/ Prof. Akkary/ Prof. Mazen	
Minutes taker	Alex Semaan	
Agenda Item: General Project Discussion		
Discussion		
We started by presenting our research findings and work from last week: • A simple Block Diagram of our design showing in a simple way how the system would execute. • An FYP project containing information about the sensors' network for a precision agriculture purpose.		
Conclusions		
• The Data collected from the FYP report given to us by Dr. Imad El Hajj is very important as it allows us to jump to data analysis and focus on machine learning as well as the other interfaces and areas of our design. • We have to define the crops we will study which crops are the most common in Lebanon and those that		

Action Items	Person Responsible	Deadline
Meet with agriculture department as well as Fix our crop target to aim at high market value crops with usually smaller yield and higher value (like vineyards/flowers -> tulips/roses etc..)	Johnny Nader Majd Nasrallah Alex Semaan	In 2 weeks

Non-Technical constraints	
Discussion	

Non-technical constraints that we discussed: • Make an easier/non-frequent maintenance for the power. • Avoid wirings as much as possible in our design. • Have low energy consumption sensors.			
Conclusions			
• Resort to solar energy and battery storage • Having a communication system between sensors through Zigbee. • Finding non power-hungry sensors that are just as accurate.			
Action Items		**Person Responsible**	**Deadline**
Research more solutions to these constraints		Johnny Nader Majd Nasrallah Alex Semaan	By next meeting

Meeting #: 5			
Date: 7.6.2011	Time: from 4 to 5	Location: RGB Library	
Meeting called by	The group		
Attendees	Majd Nasrallah/ Johnny Nader/ Alex Semaan		
Minutes taker	Johnny Nader		
Agenda Item: General Project Discussion			
Discussion			
We started by presenting our research findings and work from last week: • A refined block diagram of our system • Alternative communication methods other than Zigbee.			
Conclusions			
• We will analyze the different Machine Learning techniques available for sensor networks. • We found that Zigbee is the best alternative for connecting our sensor network. • Look into diverse crops since the changes in needs are minor.			
Action Items		**Person Responsible**	**Deadline**
Fix our crop target to aim at high market value crops with usually smaller yield and higher value (like vineyards/flowers -> tulips/roses etc..)		Johnny Nader Majd Nasrallah Alex Semaan	In 1 weeks

Non-Technical constraints		
Discussion		
Non-technical constraints that we discussed: • Have good proof of effectiveness since farmers might not trust our system. • Have a topological study of the fields before system installation. • Have good security and privacy of our servers. Hackers could flood the crops with the irrigation system for		
Conclusions		
• Might not need solar since the system sends updates at intervals. • Look into using the AUB fields in bekaa for testing or collected data • Finding non power-hungry sensors that are just as accurate.		
Action Items	**Person Responsible**	**Deadline**
Research more solutions to these constraints	Johnny Nader Majd Nasrallah Alex Semaan	By next meeting

Meeting #: 7		
Date: 7.6.2011	Time: from 4 to 5	Location: RGB Library
Meeting called by	The group	
Attendees	Majd Nasrallah/ Johnny Nader/ Alex Semaan	
Minutes taker	Johnny Nader	
Agenda Item: Experiment definition		
Discussion		
• It is needed to start defining the experiment in order to identify the variables that need to be evaluated (i.e the sensors to be used). • The system is targeting land that have variables and that is where the need for the system comes from		
Conclusions		
• The Experiment is to be defined as soon as possible, in order to be able to finish a prototype for the overall system that tests the different functionalities		
Action Items	**Person Responsible**	**Deadline**
Define the experiment by identifying variables and defining our target	Johnny Nader Majd Nasrallah Alex Semaan	By next meeting
The scope of the FYP		

Discussion	
• When asked whether it is important to focus on the analysis technique used for the data, and whether it is the best or not, Prof Akkary defined this to be as out of the scope of the FYP.	
Conclusions	
• The FYP focuses only on the engineering aspect and not the agriculture aspect, and therefore we should not worry about whether it is the best analysis from an agriculture perspective but from an engineering perspective	

Action Items	Person Responsible	Deadline
Stick to the Blaney-Criddle ETo formula	Johnny Nader Majd Nasrallah Alex Semaan	

Meeting #: 8		
Date: 7.6.2011	Time: from 4 to 5	Location: RGB Library
Meeting called by	The group	
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan	
Minutes taker	Alexander Semaan	
Agenda Item: Experiment definition		
Discussion		
• Discuss what we have researched in order to come up with the most efficient and most adequate experiment for the end of this semester, that would test multiple functionalities that will be integrated in the final design of our project.		
Conclusions		
• Come to a final conclusion and decision concerning which experiment to adopt for the FYP.		

Action Items	Person Responsible	Deadline
Define the experiment by identifying variables and defining our target	Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 10		
Date: 7.6.2011	Time: from 4 to 5	Location: Bechtel 509

Meeting called by	Porf. Haitham Akkary and Prof. Mazen Saghir
Attendees	Majd Nasrallah/ Johnny Nader/ Alex Semaan/ Prof. Akkary/ Prof. Mazen
Minutes taker	Johnny Nader

Agenda Item: Experiment definition

Discussion

- Discussed the list of components to order, and how to order them
- Discussed the experimental procedure

Conclusions

- Come to a final conclusion and decision concerning the experiment details to adopt for the FYP.

Action Items	Person Responsible	Deadline
Define the experiment by identifying variables and defining our target Order the components necessary	Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 11		
Date: 7.6.2011	Time: from 4 to 5	Location: Bechtel 509

Meeting called by	Porf. Haitham Akkary and Prof. Mazen Saghir
Attendees	Majd Nasrallah/ Johnny Nader/ Alex Semaan/ Prof. Akkary/ Prof. Mazen
Minutes taker	Johnny Nader

Agenda Item: Experiment definition

Discussion

- Ordered the components.
- Discussed the experimental procedure

Conclusions

- Come to a final conclusion and decision concerning the experiment details to adopt for the FYP.

Action Items	Person Responsible	Deadline
Assemble and program the system Write the report and the presentation	Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 12				
Date: 7.6.2011		Time: from 5 to 6	Location: Near IOEC	
Meeting called by	The group			
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan			
Minutes taker	Alexander Semaan			
Agenda Item: Experiment definition				
Discussion				
Present the results of our calculations and our different packaging design and come to an agreement over what to pick.				
Conclusions				
• Pick a 9V battery to power each unit as well as Plexiglas for packaging.				
Action Items			**Person Responsible**	**Deadline**
Finalize the design and start collecting data asap.			Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 13				
Date: 7.6.2011		Time: from 5 to 6	Location: Near IOEC	
Meeting called by	The group			
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan			
Minutes taker	Alexander Semaan			
Agenda Item: Experiment definition				
Discussion				
Present the different database management softwares and decide on one and choose where we will collect data from.				
Conclusions				
• Choose a random location to collect data (preferably plant in our house for convenience) and use microsoft's database SQL software				
Action Items			**Person Responsible**	**Deadline**
Start collecting data and store them on a laptop on a local database.			Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 14			
Date: 7.6.2011		Time: from 5 to 6	Location: RGB Library
Meeting called by	The group		
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan		
Minutes taker	Alexander Semaan		
Agenda Item: Experiment definition			
Discussion			
Recap what we have done so far and discuss the upcoming plan of action.			
Conclusions			

• Organize ourselves to maximize efficiency.		
Action Items	**Person Responsible**	**Deadline**
Set up a detailed schedule with deadlines for the semester	Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 15		
Date: 7.6.2011	Time: from 5 to 6	Location: Near IOEC

Meeting called by	The group
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan
Minutes taker	Alexander Semaan

Agenda Item: Experiment definition

Discussion

Talk about the how we tested the data collection from the unit on the plant in my house, and discuss problems I

Conclusions

- In order to store data properly on an excel form (preferably) to be the forwarded to a database, we must write a script that does those functionalities.

Action Items	Person Responsible	Deadline
Start storing data on the laptop using the unit on the plant and writing a script that stores the data on an excel file.	Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 16		
Date: 7.6.2011	Time: from 8am to 9am	Location: Near IOEC

Meeting called by	The group
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan
Minutes taker	Alexander Semaan

Agenda Item: Experiment definition

Discussion

Minor setback: the serial to usb adapter for the zigbee chip broke during testing, which will delay data collection a bit.

Conclusions

- Next step is to finish the plexi cover for the unit and to test that the sensors read the data well, and to collect data asap.

Action Items	Person Responsible	Deadline
Finish plexi box and test sensor accuracy with the box	Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 17			
Date: 7.6.2011	Time: from 8am to 9am	Location: Near IOEC	
Meeting called by	The group		
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan		
Minutes taker	Alexander Semaan		
Agenda Item: Experiment definition			
Discussion			
Minor setback: the serial to usb adapter for the zigbee chip broke during testing, which will delay data collection a bit.			
Conclusions			
• Next step is to finish the plexi cover for the unit and to test that the sensors read the data well, and to collect data asap.			
Action Items		**Person Responsible**	**Deadline**
Finish plexi box and test sensor accuracy with the box		Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 18			
Date: 7.6.2011	Time: from 8am to 9am	Location: Near IOEC	
Meeting called by	The group		
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan		
Minutes taker	Alexander Semaan		
Agenda Item: Experiment definition			
Discussion			
Started website, collecting data and order serial to usb converter for zigbee.			
Conclusions			
• We need to find a good equation for machine learning and keep collecting data			
Action Items		**Person Responsible**	**Deadline**
Keep collecting data, find a good equation for machine learning and collect the adapter from the ECE labs.		Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 19		
Date: 7.6.2011	Time: from 8am to 9am	Location: Near IOEC
Meeting called by	The group	
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan	
Minutes taker	Alexander Semaan	
Agenda Item: Experiment definition		
Discussion		
Need to find a good machine learning algorithm and keep collecting data, and work on the website.		

Conclusions			
• We need to find a good equation for machine learning and keep collecting data			
Action Items		**Person Responsible**	**Deadline**
Keep collecting data, find a good equation for machine learning and collect the adapter from the ECE labs.		Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 20		
Date: 7.6.2011	Time: from 8am to 9am	Location: Near IOEC
Meeting called by	The group	
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan	
Minutes taker	Alexander Semaan	
Agenda Item: Experiment definition		
Discussion		
Pick one of the machine algorithms found and keep collecting data, and work on the website.		
Conclusions		
• We need to pick the best equation for machine learning and keep collecting data		

Action Items	**Person Responsible**	**Deadline**
Keep collecting data and choose the best equation for machine learning.	Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 21		
Date: 7.6.2011	Time: from 8am to 9am	Location: Near IOEC
Meeting called by	The group	
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan	
Minutes taker	Alexander Semaan	
Agenda Item: Experiment definition		
Discussion		
Talked about next steps to complete: use machine learning to analyze collected data properly and progress with the		
Conclusions		
• We need to finish up the machine learning part so we can start writing our final report.		

Action Items	**Person Responsible**	**Deadline**
Work on the website and use collected data with the machine learning algorithm chosen.	Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting

Meeting #: 22				
Date: 7.6.2011		Time: from 8am to 9am	Location: Near IOEC	
Meeting called by	The group			
Attendees	Majd Nasrallah/ Johnny Nader/ Alexander Semaan			
Minutes taker	Alexander Semaan			
Agenda Item: Experiment definition				
Discussion				
Finish machine learning and website and start final report				
Conclusions				
• We need to finish up the machine learning par, finalize experiment so we can start writing our final report.				
Action Items			**Person Responsible**	**Deadline**
Start final report and finish experiment			Johnny Nader Majd Nasrallah Alexander Semaan	By next meeting