No soil spoiled

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Abstract

Climate change is a significant challenge in Egypt. It is becoming a more serious threat, and adapting to it is critical right now. After extensive research on previous solutions and the problem itself, many solutions were discovered. The best solution is an agricultural adaptation to severe climate change effects on soil, such as drought caused by global warming. This can be accomplished by comprehending the relationship among temperature, humidity, and soil moisture. Because the soil moisture percentage required for plant growth varies from crop to crop, so the chosen solution is to create an application that can determine the relationship between the aforementioned parameters and calculate the amount of water required to regulate the soil moisture percentage based on the crop to be grown and the current soil moisture percentage. The solution cannot be efficient unless the design requirements, such as dynamic range and signal-to-noise ratio, are met. After the prototype was implemented and the test was finally made, it showed efficient results as the sensors reached their maximum desired range. These desired results won't be reached without using a low error sensor with a high range such as the DHT22 sensor and a powerful heat source.

Introduction

With the current rise in the Earth temperature, Egypt is facing numerous grand challenges such as working to eradicate public health issues, and reducing pollution fouling the air, water, and soil which would then help solve the challenge of adapting to the effect of climate change. These challenges can be solved using both software and hardware interfaces. That's why the problem chosen to be solved is to design an IoT system that collects and analyzes data regarding temperature, humidity, and soil moisture then illustrate their relations and how they affect the environment negatively. Then, a mobile application that aims to spread awareness about the global warming phenomena of the drought was curated. The sensors readings were illustrated in the form of graphs and charts and processed using an ESP32 board. In order to solve this problem, it's imperative to research the previously done solutions. One of the most prominent of these solutions is **Measuring the impact of climate change on Indian agriculture.** A strength point of this solution is that it ensures that the results were accurate since the experiments were perfectly controlled as all factors were held constant while a certain climate change parameter or CO_2 level was varied. However, it's not free of flaws. Its weaknesses have come to the surface when the tests measured multiple characteristics rather than just one and used a variety of farming techniques, they were expensive and overstated the harmful effects of climate change. Another solution tried before is **Smart Agriculture for Sustainable Food Security Using the Internet of Things (IoT).** A strength point of this solution is that it can save money and the environment at the same time it also can estimate revenue and profit for farmers. On the other hand, it has the disadvantage of short battery life and path loss. By understanding these solutions, the design requirements for the chosen design are set. These requirements include the dynamic range, i.e., a wide measurement range between the minimum and maximum value for each parameter that the sensor can measure as well as an accurate measurement system with a precision that doesn't go above 0.5 changes. Another requirement is the Signal-to-noise ratio which measures the quality of the sensor and the system. To meet these design requirements, the chosen solution is a mobile application that illustrates the relationship between temperature, humidity, and soil moisture.

Materials & Methods

Table1: illustrates the used materials.

Item	ESP 32 development board	Soil moisture sensor	DHT22 sensor	Breadboard	Glass box
Image					
Source	Makers electronics	Makers electronics	Makers electronics	Makers electronics	Glass shop
Quantity	1 item	1 item	1 item	1item	1 item
Usage	Wireless WI-FI connection between the sensors and the application	Measuring soil moisture	Measuring temperature and humidity	Connecting the sensors to the ESP board	Isolating the soil
Cost	260 EGP	55 EGP	105 EGP	20 EGP	60 EGP

Total cost: 500 EGP

Methods:

First, 1 kilogram of clay soil is put in a glass container to isolate it from external factors that can cause errors in the measurements of sensors. The glass container is made to have a lid with two holes to enable the connections between sensors and the board. Then, the incandescent light bulb is hung through a hole under the lid of the box and it is connected to an external source of electricity using wires. After that, the soil moisture sensor, which consists of a measuring probe, a detector module, and wires; is inserted in the soil. The sensor uses the two probes to pass current through the soil and then it reads the resistance to get the moisture level. Dry soil conducts poor electricity while high electricity will indicate the presence of more water. The probe is connected to the main module via wires.

The DHT22 sensor is hung above the soil on the walls of the glass container because it is not waterproof. It can measure temperatures ranging from -40 to +80 °C with an accuracy of ± 0.5 °C. Next, both of the modules of the two sensors are connected to the breadboard outside the glass container using wires that pass through the hole in the wall of the box. Finally, the ESP board is connected to the breadboard directly from one end and to the laptop using a wireless WI-FI connection from the other end to collect and analyze the data that is used in the application **as shown in figure 1**.

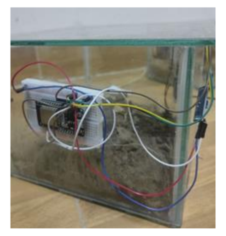

Figure 1: illustrates the final prototype.

Application:

The application is designed to have three pages which are Home, Graphs, and Bot. Each of them is discussed in detail:

1. Home page:

The home page is divided into three columns. The first column shows a large animation while the second one is divided into 3 parts for the soil moisture, the humidity, and the temperature, and the third column shows the live measurements of each parameter along with an animated icon for each parameter **as shown in figure 2**.

Figure 2: illustrates the home page of the application.

2. Graphs page:

The graphs page is a scrollable page that shows 4 different graphs (one between the soil moisture and the time, one between the temperature and the time, one between the humidity and the soil moisture, and one between the temperature and the soil moisture) **as shown in figure 3**. The values on the graphs are displayed every second and when the values on the axes exceed 10 values, the application starts to remove the older values to control the spaces between the values and prevents their interference.

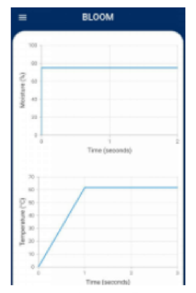

Figure 3: illustrates the graphs page of the application.

3. Bot page:

On the bot page, the user can ask the bot about the temperature in a certain government in Egypt and the bot provides data about the accurate temperature in ºC. Moreover, the bot provides data about the preferred soil moisture for a certain plant in clay soil. If the user asks a question that the bot doesn't understand, the bot asks the user to repeat the question. When the user types in "Hi" the bot asks the user how it could help them **as shown in figure 4.**

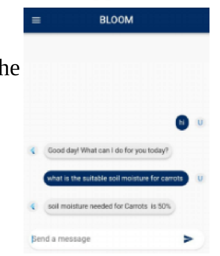

Figure 4: illustrates the bot page of the application.

Codes for the application:

https://drive.google.com/drive/folders/1HComXUl8YnVLuJGCH8FvDmyZn7_X329-?usp=share_link

Codes for the sensors:

https://drive.google.com/drive/folders/1w2g7_iQulqzQLT2h3xbwA1WtnlaRss0Z?usp=share_link

Test plan:

Some design requirements were chosen to test the efficiency of the prototype. The design requirements are:

- Dynamic range
- Signal-to-noise ratio

1. Dynamic range:

For the DHT sensor, the soil is put in a glass container with only the sensors and a heat source from a lamp as shown in figure 5. It is necessary to take a reading of temperature first. The heat inside the box then rises as the lamp is turned on. The temperature sensor registers an increase as the temperature rises until it reaches a certain point where it no longer registers a difference in the results. The outcomes are recorded so that the sensor's range can be observed. For the soil moisture sensor, the soil moisture sensor is embedded in the soil within the same box. The initial reading is interpreted as 0% because the soil had no moisture content. The gradual addition of water to the soil causes the soil's moisture to gradually rise until it reaches a point where there has been no change. The outcomes are then accurately recorded.

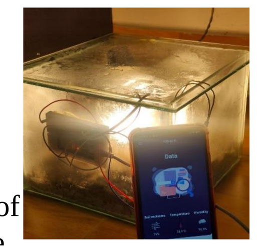

Figure 5: illustrates the prototype during the test plan.

2. Signal-to-noise ratio:

For the DHT sensor, the DHT22 sensor is positioned in the glass box with a temperature-humidity meter. Readings are taken from both devices and comparisons between the results are made. The heat source is switched off and with that, the sensor is observed to either have a change or not in the output. For the soil moisture sensor, the process of adding water is stopped then the readings are observed to either change or not. Then, the soil moisture sensor is moved out of the soil and the readings are recorded.

Results

In the signal-to-noise ratio test, a temperature–humidity meter was used to detect the sensor noise and error. The results showed a little change in the output as there was no change in the input. The results shown on the meter had no difference from the ones shown in the application. In the dynamic range test, several trials were made to test the range of the sensors **as shown in table 2.**

In the first trial, an LED lamp was used as the heat source to make a variation in the temperature. The temperature and the humidity were measured using a DHT11 sensor while the soil moisture was measured using a soil moisture sensor. The acquired results were not acceptable as the maximum range measured for the temperature was 26˚C and the humidity was 66%. The soil moisture at this temperature and humidity was measured to be 83%. **In the second trial,** a different heat source was used. The DHT11 sensor showed a limited range of measurements. The range of the temperature was between 22˚C and 50 ˚C. The error was proven to be ± 2 ˚C. For the humidity, the range was between 20% and 90% and with an error that equals ±5%.

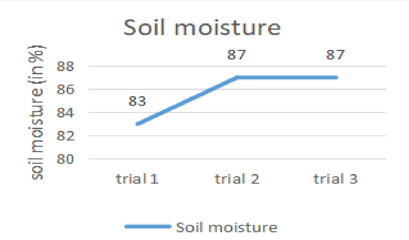

Figure 6: illustrates the soil moisture during the three trials.

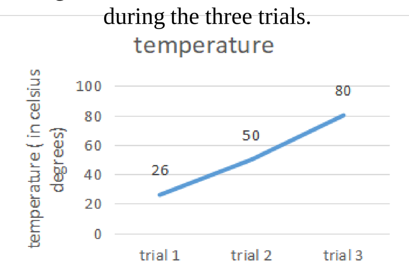

Figure 7: illustrates the temperature data during the three trials.

The soil moisture sensor range was quite acceptable as its results varied from 0% to 87% and that is the required range for the project. **In the third trial**, a different DHT sensor was used as the DHT11 was replaced with DHT22. In this trial the results were acceptable. For the temperature, The DHT sensor ranged from 22 ˚C to 80 ˚C with ±0.5 error and for the humidity, it ranged from 29% to 99.9% with an error that does not exceed ±2% and the soil moisture remained the same. The results showed progress in the measurements from the first trial to the third as shown in **figure 6** and **figure 7**.

Table 2: illustrates the test plan's three trials.

Trial	temperature	humidity	Soil moisture
1	≤26 ˚c±2 ˚c	≤68%±5%	≤83%±1%
2	≤50 ˚c ±2 ˚c	≤90%±5%	≤87%±1%
3	≤80 ˚c ± 0.5˚c	≤99.9%±2%	≤87%±1%

Analysis

The continuous rise in the Earth's average temperature due to climate change poses a great threat to different environmental parameters. That's why this semester's capstone aims to spread awareness about global warming to mitigate a climate phenomenon, in this case, the phenomenon of drought. Therefore, the chosen problem to be solved is to design an IoT system that collects and analyzes data regarding climate change parameters and then illustrates their relations in the form of graphs and charts by a mobile application. Thus, analyzing the data regarding temperature, humidity, and soil moisture was chosen to mitigate the chosen phenomena. So, a sample of clay is isolated in a glass box with a lamp that's used as a source of heat and two sensors that can achieve the assigned design requirements of signal-to-noise ratio in the communication channel and dynamic range for the sensors.

These sensors are connected to an ESP32 board through wireless transmission of the collected data by a WI-FI connection to a laptop to build a mobile application that can display graphs and charts as well as a bot that can answer questions about the suitable crops that can be planted with certain soil moisture **as shown in table 3**.

Table 3: illustrates the required soil moisture for the crops to grow.

crops	Soil moisture%
cabbage	60%
broccoli	70%
potatoes	70%
cauliflower	60%
lettuce	60%
bean	50%
radish	70%

The sensors detected very little noise due to the WI-FI connection used. The WI-FI connection makes the delay between values significantly small, unlike the Bluetooth connection where its noise increases as the range increases. The communication system showed a noise of only 0.8 in terms of temperature. Making the signal to noise ratio almost 36 dB as calculated by the following equation:

$$SNRdB=10\log_{10}\left(\frac{Asignal}{Anoise}\right)^2 = 10\log_{10}\left(\frac{61.8}{0.8}\right)^2 \approx 35.64\ dB$$

Moreover, after conducting several trials to provide a dynamic range of the sensing system, it was proved that the DHT22 provides a wider range in terms of both humidity (up to 99.9%) and temperature (up to 80˚C) than the ranges of humidity (20% to 90%) and temperature (up to 50˚C) of DHT11. The soil moisture sensor also manages to achieve this design requirement by setting a range of 0% to 87% through the different trials **as shown in figure 8.**

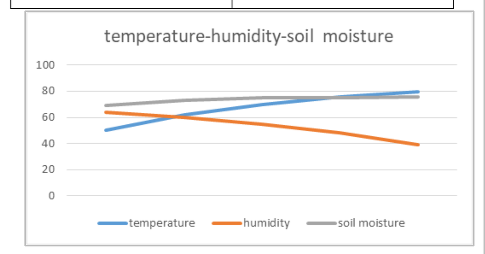

Figure 8: illustrates the relation between the three parameters.

Scientific laws and theories used during this process:

The signal-to-noise ratio equation: $SNRdB = 10\log_{10}\left(\frac{Asignal}{Anoise}\right)^2$

The formula for the error value: $\%error = \left|\frac{maximum\ value - minimum\ value}{maximum\ value}\right| \times 100\%$

The scientific theories where: As the temperature increases, the humidity decreases and the soil moisture decreases.

Learning outcomes:

PH.3.04 (communication): Each sensor is wired to either an ESP board or an Arduino. The board uses WIFI which can use a wireless channel to transmit radio signals. This analog data is received by the sensor-specific mobile or desktop application and converted into digital data. On the screen, the binary code will be interpreted or translated to display the actual context.

PH.3.01 (waves): Waves are required for establishing a wireless data connection, which is required for an IoT system. Physics L.O.1 covered the idea of waves and oscillations. The different kinds of waves—which are further subdivided into longitudinal waves and transverse waves—were described as electromagnetic or mechanical waves. Transverse electromagnetic waves can travel without a wire connection or a medium which will be essential in the capstone to transmit data.

ES.3.03 (GPS): GPS has the ability to locate any position on Earth's surface. The working mechanism of GPS is that the GPS receiver detects radio signals from nearby GPS satellites. It is highly related to the project as it has a wireless connection that connects the space segment that transmits the signal like the user segment that receives the signal like the application and the certain function or relation that connects them together.

ENW.3.1.2 (persuasive essay): Academic writing is a way to achieve the goal of proficiently getting a point across when writing academic research. Academic writing represents a good method to reflect thoughts, characters, or knowledge. It was important to learn how to write a persuasive essay to convince the reader of the essentiality of the project. The persuasive essay uses logic and arguments to convince readers of a certain point of view.

ST.3.01 (data collection and survey making): The principles of data collection were studied in statistics. This helps in understanding how collecting data about different parameters that affect climate change. In our solution, data regarding temperature, humidity, and soil moisture is collected. The samples ought to be chosen without bias. Outliers should be avoided as they affect the standard deviation. If the data set contains outliers, then the deviation from the mean will increase. However, the goal is to achieve a normal distribution. So, the maximum number of samples to be used in the process shouldn't exceed 10% of the population while the sample size should at least be 30 samples. It helps in understanding the measurement when the data is distributed to make claims about a population.

Conclusions

After testing the solution and analyzing the results, it was found that the solution met the design requirements as the testing showed that the signal-to-noise ratio of the system was significantly small because a WI-FI connection was used which causes very little noise. The dynamic range design requirement was also achieved as the range of both the DHT22 and soil moisture sensors had a wide range that covered the parameters of clay soil. The solution has managed to benefit from the prior solutions by including their pros and avoiding their cons as it managed to give accurate results that could help in increasing the crop yield as the solutions of Using a Plant Maintenance Bot for a Smart Irrigation System and using IoT in Remote Soil Monitoring. At the same time, it avoided the cons by using fewer and better sensors with a WI-FI connection which resulted in a faster collection of data, lower power utilization, and the absence of necessity of frequent maintenance. It was concluded from the data collected that as the temperature increases, the soil moisture decreases. This affects agriculture negatively as it increases the required amount of water. So, to mitigate this effect of climate change, it's imperative to find alternative irrigation methods that can reduce the amount of water needed such as adding organic matter to soils to reduce water consumption. The use of decomposed matter as a fertilizer increases the soil's ability to hold water. This organic matter such as mulch reduces surface evaporation and regulates soil temperature, thus increasing the soil's ability to retain water. However, the problem lies in raising the soil organic matter content. This is a lot easier in cool and temperate climates than in sub-tropical and semi-desert areas. In these hot climates the sun rapidly burns away the added organic matter. Here it is recommended to apply woven cloth to the organic material.

Recommendation

Recommendations for future works:

1) When applied on a larger scale, farmers ought to monitor land surface conditions of soil moisture at a minimum depth of 4 cm as the value of the temperature, humidity and moisture remain relatively stable. However, when measured at a lower depth, the accuracy of the sensor values decreases as they become affected by external factors.

2) LoRA (long-range radio) can be used to provide the output data straight to the user wirelessly instead of WI-FI when a lower bandwidth is used as it is more dynamic and less costly without internet connectivity

3) A GPS module with a camera can be fitted to determine the amount of moisture in a specific area and periodically record meteorological and ground conditions to monitor crops and their health.

4) The creation of mobile applications in regional languages to enable landowners to quickly assess the environmental conditions of their property and the health of the soil using a handheld device.

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