Capstone portfolio

Grade 12, Semester 1, 2022/2023

Project name: No Soil Spoiled

Team No: 12306

Rodina Ayman, Rowan Mahmoud, Yasmeen Nabeel

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I. Present and Justify a Problem and Solution Requirements

Egypt Grand Challenge(s):

- Improve the use of alternative energies.
- Recycle garbage and waste for economic and environmental purposes.
- Deal with urban congestion and its consequences.
- Work to eradicate public health issues/diseases.
- Increase the industrial and agricultural bases of Egypt.
- Address and reduce pollution fouling our air, water, and soil.
- Improve uses of arid areas.
- Manage and increase the sources of clean water.
- Deal with population growth and its consequences.
- Improve the scientific and technological environment for all.
- Reduce and adapt to the effect of climatic change.

1. Improve the scientific and technological environment for all

The evolution of the weather and climate information system is driven by advances in science and technology (as shown in figure 1). National Academies of Sciences, Engineering, and Medicine determine what observations to make, how information should be measured, and what products to create based on scientific, operational, and, increasingly, business requirements. The new capabilities that arise from this evolving system can dramatically alter what sectors are doing or want to do, affecting public, private, and academic partnerships. Making accurate measurements to determine how the climate change problem impacts us aid in overcoming the problem or adapting to it in a way that does not negatively impact people.

Figure 1: Improve the scientific and technological environment. https://bit.ly/39d1G6q

Weather and climate events occur on a wide range of scales, from floods in a farmer's field to global weather patterns influenced by changes in the jet stream.

To study these many phenomena and develop products and methods to reduce their effects, data with varying spatial coverage and resolution must be acquired from a variety of satellite sensors, local arrays, and independent stations. Putting this type of technology under research clearly helps

Egypt's technical and scientific environment to improve, particularly when studying the many parameters

2. Address and reduce pollution fouling our air, water, and soil

Water, air and soil are the most precious resources on Earth. Humans cannot afford to lose any of them. That is why the country strives to protect and maintain those valuable resources. Unfortunately, climate change has a major role in polluting the three of them.

Figure 2: illustrates how factories pollute air. https://bit.ly/3BtDMyQ

The increase of the temperature causes more water to evaporate, resulting in higher levels of atmospheric water vapor and more frequent, heavy, and intense rains in the coming years. This shift will lead to more floods. The remainder of the water drains into nearby waterways, picking up contaminants such as fertilizers along the way. When agricultural fertilizers wash into lakes and the ocean, they promote the rapid growth of algae. Algal blooms form, clogging coasts and waterways with clouds of green, blue-green, red, or brown algae. Blooms prevent sunlight from reaching underwater life and reduce oxygen levels in the water. Excess runoff eventually reaches larger bodies of water such as lakes, estuaries, and the ocean, polluting the water supply and limiting human and ecosystem access to water.

Moreover, climate change causes an increase in CO_2 levels which pollutes the air (as shown in figure 2). Although Egypt's contribution to global emissions does not exceed 1%, Egyptian cities, particularly Greater Cairo, are severely polluted. In 2019, air pollution was responsible for 90,559 premature deaths in Egypt (United Nations Environment Program, n.d.), accounting for more than 12% of all deaths in 2017. (Institute for Health Metrics and Evaluation, 2019).

Furthermore, Temperature and rainfall have an impact on many soil properties. Changes in our climate are expected to have an impact on our soils. soil degradation will have an environmental impact on our vegetation and crop production by changing factors as the soil's pH and CO_2 and nutrient concentration.

If we managed to solve the problem of continuously increasing pollution because of the impacts of climate change, many lives will be saved from spreading diseases and hunger.

3. Reduce and adapt to the effect of climatic change

In present time, it is widely accepted that climate change is an inevitable ecological disaster. Anthropogenic global warming can explain today's rise in the earth's average temperature as human industry and agriculture is now a direct cause of the increase in the concentration of greenhouse gases and therefore the increase of the planet's capacity to absorb heat. Management for climate crisis mitigation and adaptation is key for environmental conservation, hence the urgency to act and integrate adaptation planning into our policy making. IoT (internet of Things) systems have the protentional to reduce CO2 emissions by collecting data and understanding how different climate change parameters are affected by the rise of such emissions. This collection was proven to significantly help industries' greenhouse emissions by the year 2030.

4. Work to eradicate public health issues/disease

Climate change has both direct and indirect effects on human health (as shown in figure 3). Extreme heat, rising sea levels, changes in precipitation resulting in flooding and droughts, and powerful hurricanes can all cause direct injury, illness, and even death. Climate change can also have an indirect impact on health due to environmental changes. For example, rising levels of air pollution can have a negative impact on respiratory and cardiovascular conditions. Temperature and rainfall changes can affect the survival, distribution, and attitudes of insects and other species, resulting in changes in infectious diseases. Increases in precipitation, storm surge, and sea temperature can all contribute to an increase in water-related illnesses. Climate change can also have an impact on food safety by exposing people to contaminated foods, which can lead to foodborne illnesses. Furthermore, climate change can have an influence on one's mental health and well-being.

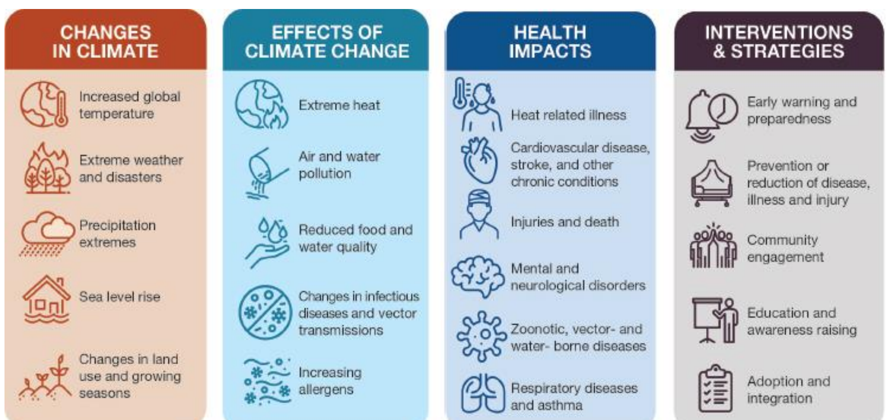


Figure 3: illustrates how climate change impacts health. https://bit.ly/3uOldSt

Solving the problem of climate change would decrease the spreading of many different diseases and injuries that can cause death. Solving this challenge is mandatory to protect people's lives and well-being.

Problem to be solved:

The livelihoods of people, species, and places are seriously threatened by climate change. Immediate actions must be taken to reduce and adapt to its impacts. That is why this semester's challenge is to design an IoT system that collects and analyzes data and then illustrates their relations and how they affect the environment negatively in the form of graphs and charts by a mobile application. Data regarding temperature, humidity, and soil moisture should be collected and processed using sensors and other components to design an application that aims to spread awareness about the problem of droughts which is a result of the global warming phenomenon.

Positive impacts of solving the challenge:

Solving this challenge would help the country in adapting to the effects of climate change and global warming. Crop production would increase and people would be more aware and educated about the negative impacts of climate change which need to be stopped immediately before we lose our dear planet Earth.

Negative consequences of not solving the challenge:

Not solving this challenge would affect the country and the whole planet greatly. Droughts in Egypt would increase and the soil wouldn't be able to grow plants due to decreasing its moisture percentage by the impact of global warming. Crop production would decrease, food demand would increase and the country wouldn't be able to provide enough food for the population which would result in increasing the spread of certain diseases.

Research:

After understanding the challenge and the threat climate change has on the world, several factors relating to this problem to understand it better were researched, including:

- Different climate change parameters (salinity, sea level rise, etc.)

Trends in worldwide average temperature, rising sea levels, upper-ocean heat content, land-based ice melt, polar ice caps, seasonal permafrost thaw depth, and other climate variables all show that the planet is warming. Multiple independent research groups from around the world have confirmed the observed trends.

- the concentration of greenhouse gases.

After research, it was found that carbon dioxide (CO_2) concentrations, the most important greenhouse gas, reached 413.2 parts per million in 2020, representing 149% of pre-industrial levels. Methane (CH_4) is 262% and nitrous oxide (N_2O) is 123% of what it was in 1750 when humans began disrupting the Earth's natural equilibrium.

- the human activity that affects the rise in the earth's temperature.

Human activities, particularly the use of fossil fuels, are causing climate change. Changes in land use and land cover caused by humans, such as deforestation, urban growth, and shifts in vegetation patterns, also affect the climate, resulting in changes in the reflectivity of the Earth's surface (albedo), emissions from burning forests, urban heat island effects, and changes in the natural water cycle.

<u>Then after understanding the problem, topics relating to the solution were researched such as:</u>

- What IoT systems are

The Internet of Things (IoT) is a system that influences how humans interact with technology. IoT refers to the process of connecting previously unconnected systems and devices. In other words, IoT gives otherwise dumb things digital intelligence. Some define IoT as the next stage in the Internet, in which things and objects with sensors and actuators are connected to the Internet to gather, send, and receive data, leading to smarter solutions and, in some cases, acting on data.

- Sensors for the measurement of soil moisture and their accuracy

The three most common measurement principles are capacitive, TDR, and FDR. The moisture-sensitive capacitor in the capacitive soil moisture sensor detects moisture. This sensor is frequently built as a prototype. TDR (Time Domain Reflectometry) is a technique that employs a crystal oscillator to generate high-frequency signals that are then transmitted to a metal probe. TDR has high independence; its results are unaffected by soil type, density, or temperature. It can also measure soil moisture when it is frozen. TDR sensors are complex in design and thus costly. FDR employs the electromagnetic pulse principle, which is based on electromagnetic wave propagation in a medium frequency, to determine the apparent dielectric constant of the soil and thus the volumetric water content of the soil. FDR has the advantages of being simple, safe, fast, and accurate, as well as having a wide range and simple calibration.

- Different types of temperature and humidity sensors

Temperature sensors are classified into four types: thermocouples, RTDs (resistance temperature detectors), thermistors, and semiconductor-based integrated circuits (IC). The main types of temperature sensors used today are thermocouples, RTDs, thermistors, and semiconductor-based ICs. Thermocouples are inexpensive, long-lasting, and capable of measuring a wide range of temperatures. RTDs have a wider temperature range (though they are smaller than thermocouples) and provide accurate and repeatable measurements, but they are slower, require an excitation current, and require signal conditioning. Although thermocouples are small and durable, they are less accurate than RTDs and require more data corrections to interpret temperature. Semiconductor-based integrated circuits are easy to implant and can be packaged in extremely small packages, but they have a limited temperature range.

- What system noise is

Noise is unwanted electrical or electromagnetic energy that degrades signal and data quality. Noise occurs in both digital and analog systems and can affect all types of files and communications, including text, programs, images, audio, and telemetry.

- How different crops react to different soil moisture percentages.

When the required levels of moisture are unavailable in their habitat soil, plants experience or exhibit symptoms of extreme water deficiency. This occurs when plants continuously lose water through transpiration or evaporation as a result of high temperatures, and the loss of ground moisture is not repaired. This extreme dryness, known as drought, that lasts for long periods is widespread on a global scale.

- The use of ESP boards in IoT systems

ESP boards are low-cost Wi-Fi chips with built-in flash chips that allow you to build a single-chip device that can connect to Wi-Fi. Newer versions, such as the ESP32 boards, also include BLE (Bluetooth low energy), and there are numerous boards to choose from.

Other solutions already tried:

1. Measuring the impact of climate change on Indian agriculture

This report's research examines how Indian farms operate in various climates. The study's objective is to investigate farm behavior and determine whether there is any proof that farmers in emerging nations like India now adapt to their local climates. The reported research assesses how sensitive low-capital agriculture is to climate change. They investigate whether actual farm production is as climate-sensitive as agronomic models predict under the supposition of no adaptation. The studies also compare the climate sensitivity of small farms to estimates that have previously been adjusted for agriculture in the United States. The analyses use a cross-sectional analysis of farm performance across several climate zones, known as the Ricardian approach. The approach makes use of farm value or net farm revenue as an economic indicator of farm performance. Performance is compared over a broad area where farms are located in various local climates. One can empirically determine long-term climate sensitivity by regressing farm performance on long-term climate.

Pros:

- the experiments were perfectly controlled
- the results were accurate and removing one possible weakness of the Ricardian method.

Cons:

- they were expensive
- they overstated the harmful effects of climate change.

2. A Smart Irrigation System Using Plant Maintenance Bot

Plant maintenance bot is a novel approach to developing a robot to water plants by monitoring soil moisture content and detecting disease within the plant. To obtain results quickly and efficiently, the entire operation is fully automated. The bot is entirely dependent on embedded systems, for which a specific code has been written. The robot is used to detect disease in plants and recognize moisture content in soil without the need for human intervention. The IOT system is designed using an Arduino UNO board that includes numerous options for gathering customer necessities by simply connecting it to a PC via a USB interface and powering it with an AC to DC converter or battery. The board is connected to a soil moisture sensor that measures the volumetric water content of the soil and a water-level sensor that is used to determine the level of water in a tank or another piece of equipment. The bot moves and collects data about the soil's dampness using the sensors and sends the data to be analyzed by the Arduino (as shown in figure 4). After analyzing the data, the board gives orders to motors to irrigate the soil according to the water level and soil moisture measurements.

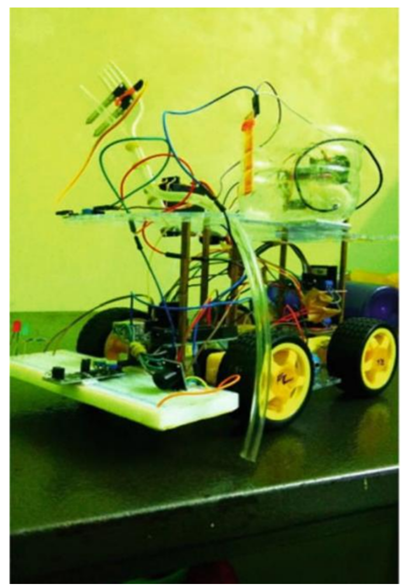


Figure 4: illustrates the final prototype of the bot. https://bit.ly/3YjIh8Z

Pros:

- Gives accurate measurements and commands that help keep soil protected and increase crop yield.

Cons:

- Takes a long time to analyze the data and give commands.
- Complex and may require frequent maintenance.

3. Framework for Internet of Things in Remote Soil Monitoring

A soil monitoring system based on the Internet of Things (IoT) is used to maximize crop or plant yield by observing soil parameters and providing the necessary information to farmers remotely. For remote sensing, agricultural soil sensors are used.

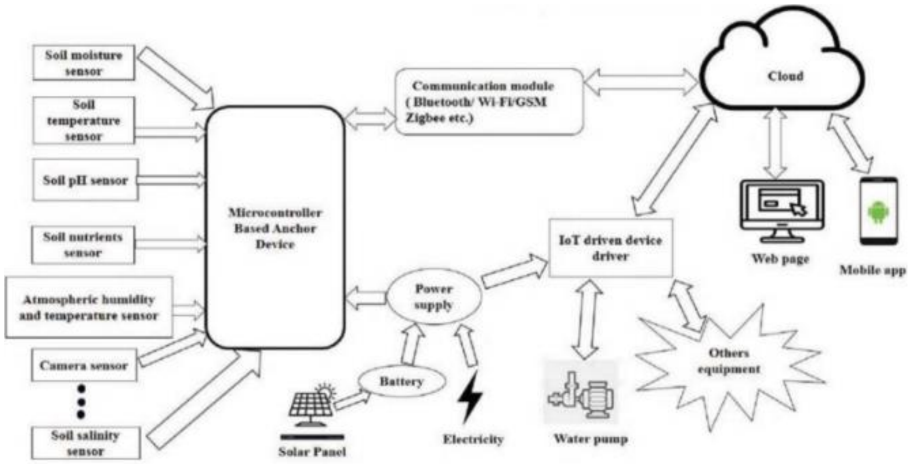


Figure 5: illustrates the connections of sensors with the board and the devices. https://bit.ly/3UMw4a4

Optimal resource utilization is critical in real-time sensor data monitoring. After analyzing the collected data, one can draw useful conclusions about crop, fertilizer, and other field recommendations. IoT influences farmers to monitor crop growth, soil moisture, soil temperature and humidity, soil nutrients, and so on by using sensors to remotely manage and control irrigation equipment and make quick decisions. Farmers can take appropriate and precautionary measures using apps on their smartphones and web pages. The farmer is informed of the current soil and crop status in their field by IoT-connected sensors. A massive network of devices communicates with one another in an automated mode that requires no human interaction. It would also assist him in monitoring and adjusting the soil parameters required to increase crop production. Various soil parameters influence proper and efficient cultivation. For this measurement, soil sensors such as pH sensors, moisture sensors, nutrients sensors (NPK sensors), temperature and humidity sensors, salinity sensors, and so on can be used. The soil moisture, soil temperature, temperature, and humidity sensors can all be integrated into this proposed system for an effective irrigation system. Saltwater intrusion can be detected using the salinity sensor. A soil pH sensor determines whether the soil is acidic or alkaline. Soil salinity, pH, and nutrient sensors can all be used in a fertilizer recommendation system. The camera sensor can be used to provide images of crops or plants. Crop diseases can be diagnosed using image processing, and farmers can then take the necessary steps. The data collected by these sensors is sent to the anchor device. The anchor device processes the sensed data and sends it to the cloud via a wireless communication module (Bluetooth/ Wi-Fi/ Zigbee/Radio/GSM, etc.). Machine learning or automatic data analysis can be performed on these IoT data in the cloud and useful information extracted for farmers to make the best decision (as shown in figure 5).

Pros:

- Easy to implement
- Increases crop yield efficiently

Cons:

- High power utilization
- Complicated data

4. Smart Agriculture for Sustainable Food Security Using Internet of Things (IoT)

The Internet of Things (IoT) is being used in many facets of human life (domestic and commercial) to improve resource efficiency, increase productivity, and provide ease of living. One of them is agriculture, where IoT and robots are used both before and after the cultivation process, from preparing the land for cultivation to supplying them to the consumer market. Crop monitoring, intelligent irrigation, pest monitoring and control, harvesting, and safely supplying them in the consumer market while preserving the caliber and integrity of the finished product are some of these domains. In terms of cutting-edge agricultural technology, Pakistan is an agricultural nation. UAV was used in this solution. UAVs can be used in both the monitoring and execution phases of an application. The following are two common ways that UAVs are used in precision agriculture. The first is monitoring, where applications include soil and crop mapping and sampling, yield forecasting, weed, and pest detection, and disease and stress assessment of the soil and crops. The second is the application phase where fertilizer, pesticides, herbicides, and seeds are applied.

Pros:

- it can save money and the environment at the same time
- Farmers can estimate revenue and profit, lower labor and operating costs, assess diseases and pests accurately, and schedule and plan more suitable harvests thanks to these applications.

Cons:

- Short battery life
- path loss while communicating wirelessly due to the surrounding environment

5. Smart Farming Implementation using Phase-based IoT System

This system provides great help in soil health monitoring for farmers as it manages different soil parameters caused by climate change such as moisture and pH through an application that implements IoT, cloud computing, and sensing systems. The soil health monitoring system helps farmers understand the current state and requirements of the soil. This helps in making sure when the soil needs to be looked after and how exactly it should be done with the help of various sensors such as a soil moisture sensor (EC-05), a soil pH sensor, and a soil temperature and humidity sensor (DHT-11). This model functions in three major phases:

1)The physical phase that consists of the prototyping module.

2)The median phase that conducts the process through a wireless medium.

3)The application phase that determines the use of the application created

Pros:

The data flow throughout the system from where data is collected and that it is transported from one phase to another is the model's most noticeable aspect. Also, the gathering and storage of the data, as additional data gathered is not only stored but also used for future verification.

Cons:

The primary disadvantage is the delay in monitoring caused due to returning soil samples to the lab for analysis.

II. Generating and Defending a Solution

Solution and Design requirements:

Solution requirements:

Several goals are to be met when generating a successful solution to a problem. This is done by observing then identifying such problem. Then, creating and following a list of procedures that ought to be taken. Data analysis is an essential component to finding a solution for the issue of climate change. That's why the leading goal for this semesters challenge is to collect the data of how different climate change parameters are affected by the annual increase in temperature.

Design requirements:

1) Dynamic range:

Choosing a sensing system that provides a wide measurement range between the minimum and maximum value for each parameter that the sensor can measure is essential to the validity of the data analysis process. Moreover, the system ought to involve an accurate measurement system with a precision that doesn't go above 0.5 changes, making it possible to make claims about shifts of 0.5 degrees provided by the prediction model.

2) Signal-to-noise ratio:

To calculate the usefulness of the sensing system, it's a must to measure how the inputs and the outputs the sensors provide affect one another, to make trusted claims about their relationship and how they impact the environment. If the inputs do not change but the outputs change, it means the has an error making this a system noise. Measurements below these noise values cannot be trusted because it indicates the poor quality of the sensor and the system.

Selection of Solution:

The solution was selected to be a mobile application. The relationship between temperature, humidity, and soil moisture will be illustrated on a good graphical interface as all of those parameters are affected by global warming and a significant change in them may cause drought. Aside from displaying the measurements of those parameters as well as the change and function of the relationship, the amount of water that should be added based on the needed soil moisture percentage will be shown on the application and will include a bot assistant that can be used by farmers as it answers the asked questions. The solution is primarily used on clay soil, which is the most commonly used soil in agriculture in Egypt, and crops such as potatoes, peas, carrots, and tomatoes. The application will assist farmers in adapting to the climate change crisis by providing them with the metrics they need to avoid issues such as planting seeds in soil that has lost moisture and cannot support crop growth. Temperature, humidity, and soil moisture have the greatest influence on those parameters, which is why they were specifically chosen.

Selection of prototype:

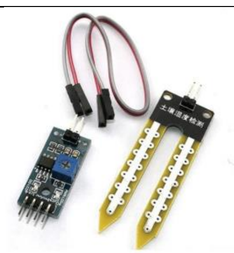
A sample of clay soil will be isolated in a glass box to prevent any external factors from affecting the soil. A lamp will be used as the source of temperature. A soil moisture sensor will be immersed in the soil while a temperature-humidity sensor ranging between -40 ºC and 80 ºC and a precision of 0.5 ºC will be hung in the glass box. Both of the sensors will be connected to a breadboard connected to an ESP32 board to transmit their collected data wirelessly by a WI-FI connection to a laptop. The data will be collected every hour. The Arduino IDE application on the laptop will be used to write the codes for designing a mobile application that can display graphs and charts illustrating the relations between temperature, humidity, and soil moisture. Moreover, a bot that can answer questions about the suitable crops that can be planted in clay with certain soil moisture will be available on the application. Every user on the application will have a profile that saves the history for the user.

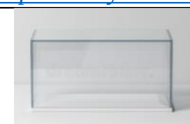
III. Constructing and Testing a Prototype

Materials and Methods

Materials:

Table 1: illustrates the used materials

Item	Quantity	Description	Usage	Cost	Source of purchase	Picture
ESP32 development board	1	Tile with integrated ESP-WROOM-32 module for a WI-FI network communication in the 2.4 GHz with a voltage of 5 V.	Wireless WI-FI connection between the sensors and the application	260 EGP	Makersel-ectronics	 *Figure 6: illustrates the ESP32 board.* https://bit.ly/3YlM8Th
Soil moisture sensor	1	A moisture Sensor uses the two probes to pass current through the soil, and then it reads that resistance to get the moisture level.	Measuring soil moisture	55 EGP	Makersel-ectronics	 *Figure 7: illustrates the soil moisture sensor.* https://bit.ly/3j2YbEw
DHT22 digital temperature and humidity sensor	1	Module with a digital interface, single-wired. Measuring range: temperature -40 to +80 °C, humidity 0-100% RH.	Measuring temperature and humidity	105 EGP	Makersel-ectronics	 *Figure 8: illustrates the DHT22 sensor.* https://bit.ly/3iOwDmi

Breadboard	1	-	Connecting the sensors to the ESP board	18 EGP	Makersel -ectronics	 *Figure 9: illustrates the breadboard.* https://bit.ly/3iOwTlg
Glass box	1	-	Isolating the soil	60 EGP	Local shop	 *Figure 10: illustrates the glass box.* https://bit.ly/3PuPA9Z
Clay soil	1 k	-	Testing its soil moisture	0 EGP	Farm	 *Figure 11: illustrates the clay soil.* https://bit.ly/3Fn9bnN
Total cost: 500 EGP						

Methods:

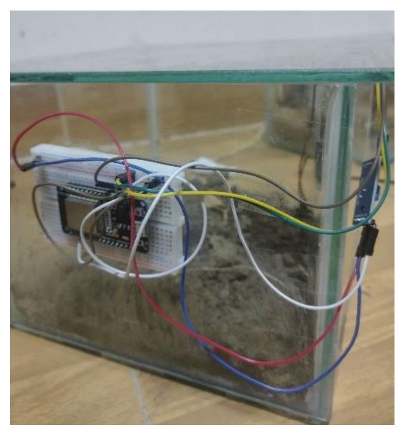


Figure 12: illustrates the final prototype.

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 12).

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 13).

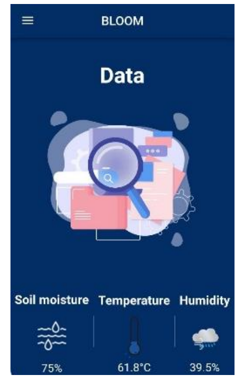


Figure 13: illustrates the home page of the application.

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 14). 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.

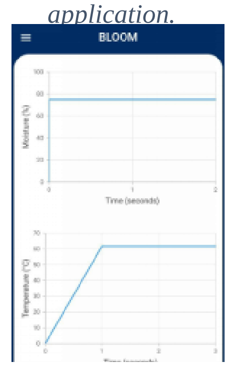


Figure 14: illustrates the graphs page of the application.

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 ⁰C. 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 15).

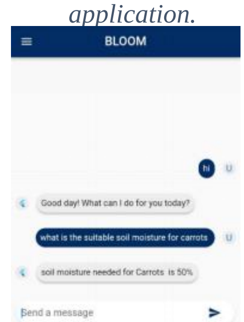


Figure 15: illustrates the bot page of the

How the application was coded:

First, the main function of the application was written to identify the firebase which proves the options for the application, and the code to run the widget "MyApp" was written (as shown in figure 16). Then, the Material App code was written to show the application's name, logo, and color on the page and identified the font's style and size (as shown in figure 18). Assets were used to put animated icons. The values and references of the temperature, the soil moisture, and the humidity were identified so that they could be recalled

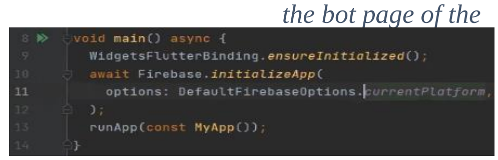


Figure 16: illustrates the code for the main function and running the application.

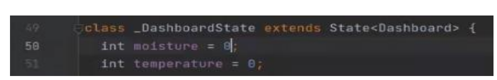


Figure 17: illustrates the code for setting the parameters' value to 0.

when needed. The values are first set to 0 and then changed (as shown in figure 17). Set state code was written to refresh the application to show new values whenever they change. Single child scroll view code enables the scrolling of the application's pages. Bounce scroll physics was coded so that when you scroll to the top or bottom of the page it bounces a little. Transparent boxes were put between the items to help control the spaces between them so they don't interfere. After that, the width of the application was set to match the width of the mobile screen while the height was set to cover only 70% of the mobile screen's height. A scaffold key was put in to make a menu on the top left of the screen that shows different pages. Three routes were set to make three different pages on the application which are Home, Graphs, and Bot (as shown in figure 19). Push Replacement Name code was put in so that when you navigate from one page to another, the page you left will be deleted and you will head directly to the desired page rather than the application closing.

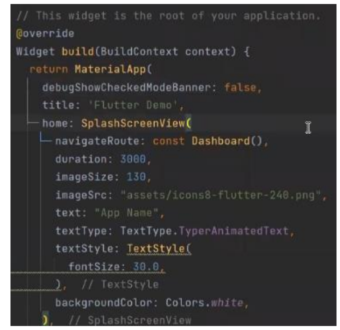


Figure 18: illustrates the code for the material app.

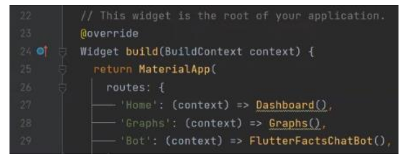


Figure 19: illustrates the code to the three routes.

After that, to design the graphs on the graphs page, the values of soil moisture, temperature, and humidity were defined again and codes for lists were made for each graph (as shown in figure 20). Next, the X and Y values for the graph were defined. For example, for the graph showing the relation between soil moisture and temperature, the soil moisture was put as the X-axis and the temperature was put as the Y-axis. The initial state of the page was set to start all graphs with initial values of (0,0). Then, the timer starts, and the values of the variables in the graphs are shown every 1 second. Void dispose was coded so that when the user exits the graphs page and returns, the graphs' values will start over rather than continue from where they left off. To draw the values in a form of a graph the type of chart was selected as line series that uses live data. Codes were also written to delete the first values on the graph's x-axis and y-axis when the time exceeds 10 seconds to provide more space on the axis for the values rather than interfering with each other (as shown in figure 21).

Figure 20: illustrates the codes for the lists.

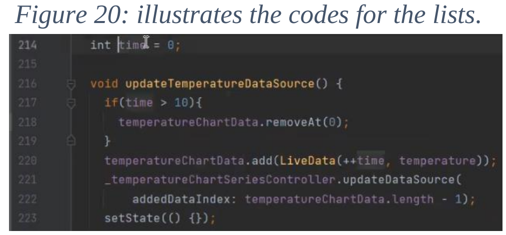


Figure 21: illustrates the codes for values on the graph.

Finally, to design the bot, a new widget was made and the bot message and user message were identified. The column was set to start to display the user's messages on the left side of the screen and the bot's messages on the right side. The data of each plant's preferred soil moisture content was organized and imported to the bot along with an already ready API that has the data of the temperature in each city in Egypt (as shown in figure

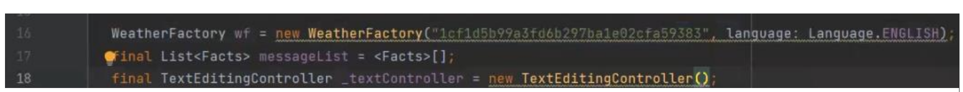


Figure 22: illustrates the codes for setting weather API.

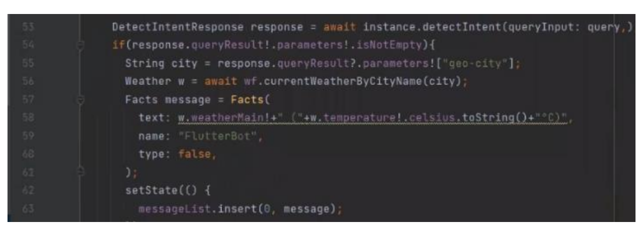


Figure 23: illustrates the codes for bot answering weather questions.

22 and figure 23). The language of the bot was set to English. The text controller helps in clearing the page as when the user sends the message, it deletes it from the text field and displays it in the chat. The list was reversed so that the latest message appears at the bottom of the list view.

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

Safety precautions:

Safety is very significant and should be noted by the team especially safety during the experiments. The safety precautions were as follows:

- The safety gear of the laboratory (coats, vests, gloves, and safety goggles) must always be worn while dealing with electricity.
- The work must always be done with a supervisor being near.
- Any type of toxic material with unknown toxicity is considered a hazard (highly toxic) and should be avoided even if its toxicity is relatively low.

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 24). It is necessary to take a reading of the current 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.

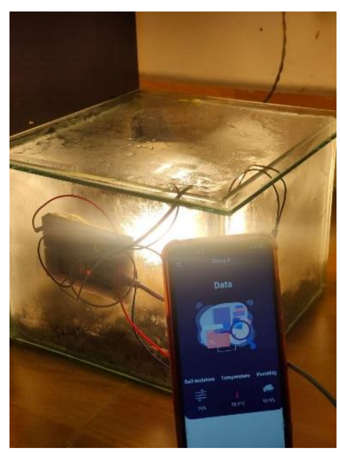


Figure 24: illustrates the prototype during the test plan.

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.

Data collection:

In the signal-to-noise ratio test, a temperature–humidity meter was used to detect the sensor noise and error. The results showed no 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).

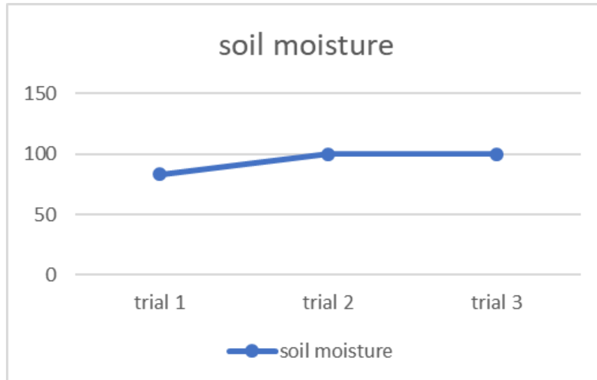


Figure 25: illustrates the soil moisture during the three trials.

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 68%. The soil moisture at this temperature and humidity was measured to be 83%.

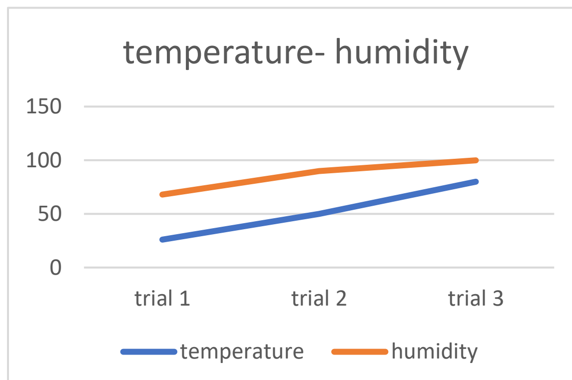


Figure 26: illustrates the relation between humidity and temperature.

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%. 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%.

The results showed progress in the measurements from the first trial to the third (as shown in figure 25 and figure 26).

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%

IV. Evaluation, Reflection and Recommendations

Analysis and Discussion

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. 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:

$$\text{SNRdB}=10\log_{10}\left(\frac{Asignal}{Anoise}\right)^2 =$$

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

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%

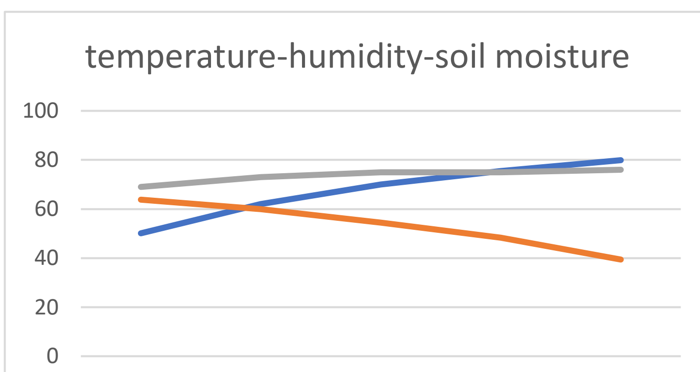


Figure 27: illustrates the relation between temperature, humidity and soil moisture.

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 27).

<u>Scientific laws and theories used during this process:</u>

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.

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 these 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.

Learning outcomes:

ES.3.03 (GPS): GPS can locate any position on Earth's surface. The working mechanism of GPS is that the GPS receiver detects radio signals from nearby GPS satellites. There are precise clocks on each satellite and in the receiver so that the receiver measures the time for radio signals from satellites to reach it. The receiver uses the time and the speed of radio signals to calculate the distance between the receiver and the satellite using the relation between speed, distance, and time (v=d/t) the distance will be determined. The receiver does this with at least four different satellites to locate its position on the Earth's surface. As you can see it is highly related to the project as it has a wireless connection that connects the space segment that transmits the signal like the input sensor and the user segment that receives the signal like the application and the certain function or relation that connects them. It was also related to the challenge as GPS may be used for weather forecasting and climate prediction.

PH.3.4 (Communication): The basic elements of communication are the transmitter, the transmitting channel, and the receiver. For the transmitter to transmit a signal it needs to encode it with a carrier wave so it can be received with the receiver's antenna. In our capstone project, sensors are all connected to an ESP board or an Arduino with a wired channel so the information can be transmitted from the sensors to the board. The board transmits radio signals which are electromagnetic radiations using WIFI which can use a wireless channel. this is analog data and it is received on the application made for the sensors on mobile or desktop and decoded into digital information (it is usually a binary code in 0s and 1s). The binary code will be translated or interpreted on the screen to show the actual context.

PH.3.01 (Waves): In physics L.O 1 the concept of waves and oscillations was studied. The types of waves were mentioned as mechanical or electromagnetic which are also classified into longitudinal waves and transverse waves. In our capstone, an IoT system is required a wireless data connection and that wireless data connection won't be made without using waves. For example, let's say that we have an IoT system of a temperature and a soil moisture sensor connected to an ESP board. How will all of the data be collected on the application? It needs a wireless connection like Bluetooth or WIFI and they both exist as radio waves which are transverse electromagnetic waves they don't require a wire connection nor do they require a medium to propagate through. Radio waves have properties of higher wavelength and lower frequency than most other EM waves. The wavelength or the frequency can be determined by a relation with the speed of the wave (v= wavelength x frequency) and by studying it more, we will get more understanding of how the signals in the wireless IoT system work.

BI.3.4 (Sensory receptors): Sensory receptors were studied in this LO. There are many different types of sensory receptors, and each one is used differently depending on the action we take. For example, a mechanoreceptor necessitates a physical force to be activated, such as stretching. Sensory receptors can be compared to components of a communication system applied in the capstone project. Because sensory receptors carry analog information, such as touch, in a process known as transduction, and it is amplified in the same process so that the information can be transmitted and received clearly. It acts as a transmitter that also encodes, amplifies, and transmits the information. It sends it via sensory neurons, which serve as a channel in this communication system. Finally, the information is transmitted to the brain (the brain receives the information so it is a receiver). The information is transmitted in a process known as transmission, and then it is integrated into the brain in a process known as perception, which is very similar to decoding in communication systems.

CH.3.01 (Scientific method): The scientific methodology was studied in this LO. This is a process through which any scientific endeavor is done. It consists of various steps to solve the chosen problem. This is how our capstone was done. The first step is to observe the problem in order to identify it. Secondly, a hypothesis which is a proposed solution for the phenomena is formed. Then, this solution is tested multiple times until the desired results are achieved. Finally, a conclusion and analysis to such results is made.

ST.3.01 (Data collection and survey making): The principles of data collection and making a survey were studied in statistics. This helps in how collecting data about different parameters that affect climate change in order to make claims about their relation. In our solution, data regarding temperature, humidity and soil moisture is collected. Whilst collecting data, the samples ought to be chosen without a bias. Outliers should be avoided as they affect the standard deviation. Standard deviation provides the deviation from the mean value of the distribution. If the data set contains outliers then the deviation from the mean will increase. However, the goal is to the achieve a normal distribution. So, the maximum number of samples to be used for the survey 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 (a group of samples).

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.

MA.3.01 (Related-time-rate): In differential calculus, learning about the related time rate has helped with our capstone. It involved using derivatives to find the relation between the rates of two or more quantities. In our case these variables are the temperature, humidity and soil moisture, all related to time. If we choose two of these variables naming them x and y and they are related by the function y=f(x). The rate if change of y in terms of rate of change of x can be expressed using implicit differentiation and the chain rule as $\frac{dy}{dt} = \frac{dy dx}{dx dt} = f(x)\frac{dx}{dt}$

MA.3.02 (Local maximum and minimum): Local maximum and minimum are points of a function which give the maximum and minimum range. They're input values for which the function gives the maximum and minimum output values respectively. These points can be calculated by finding the derivatives of the function through the first then the second derivative. This can help in making graphs to display the dynamic range of the sensors.

CH.3.02 (Robust experimental design): In this learning outcome, the robust experimental design was studied. The robust experimental design is – similar to the EDP process – is a set of scientific steps to design an experiment. Its steps consist of choosing a hypothesis, testing it and seeing how the results turn out and learning from them. This is useful to our capstone as after the design requirements are set, a test plan is done to examine the results. After examination, negative results that turn are to be understood. The experiment is repeated until the desired results are achieved. The robust design experiment can help while measuring the signal to noise ratio of the sensing system. If the inputs do not change but the outputs change, it means the has an error making this a system noise. Meaning the experiment has to be repeated in order to decrease the error as much as possible.

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