Automated irrigation

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Ahmed Yasser - Ali Hany - Belal Mohaseb

Key words : Artificial Intelligence - Irrigation - Specialization

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A.Egypt Grand Challenges

Any successful project is based on identifying a specific problem to solve. Then search for this problem and try to find solutions. And that's what we are making in this project to make it a successful one. So, these are the challenges we searched about to solve in our capstone project:

A.1. Increase the industrial and agricultural bases of Egypt:

Agriculture is how humans started civilization all around the world a long time ago, it was the first step for humans to enter our modern civilized world. Nowadays It represents the main input for raw materials, where agriculture provides industries from its simplest to its most complex with the matter needed to be shaped, processed, and converted to most of the daily used products. That is why agriculture is in increment as shown in chart 1.

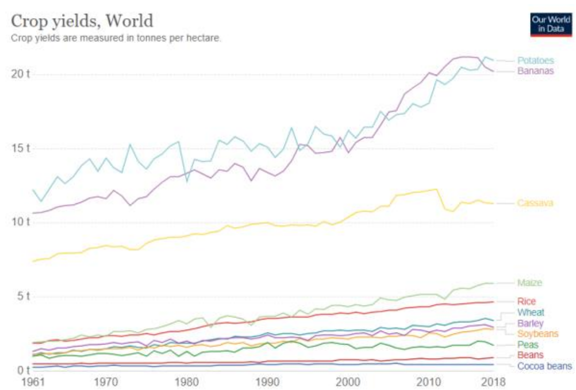


Chart 1

Increment of crops yield all over the world

https://ourworldindata.org/crop-yields#:~:text=Production%2C%20yield%20and%20land%20use%20changes%20over%20time&text=From%201961%20to%202014%2C%20global,has%20increased%20by%20280%20percent.&text=The%20average%20cereal%20yield%20has,as%20it%20did%20in%201961.

Nevertheless, as the population of the earth increases, as the materials are more needed and as the natural sources used in agriculture are more endangered. The system of agriculture has to be more regulated.

Causes:

Irrigation:

The farmers in some areas are heavily dependent on the seasonal June-September monsoon rains for irrigating crops. There is a wide difference between the yield of irrigated crops and rain-irrigated crops. Deficient rains and continuous drought cause tremendous losses to farmers. A regular supply of irrigation water is essential to sustain crop productivity. In case, one or two critical growth stages go without irrigation during the lifecycle of a crop, it results in a significant reduction in crop production. The adverse effects on the per hectare yield of crops happen due to an unprecedented water shortage. To cope with water shortage, a complete reorganization of water sector institutions through mergers, economic utilization of water resources, procurement of additional storage for crops round the year, building storage to overcome droughts, and developing comprehensive water and hydro resource policy are necessary

Nutrients application:

Agricultural soils contain very low organic matter. Also, nutrient deficiency is widely reported because of the harvesting of exhaustive crops year after year, high temperature, low-rainfall, high-cost, and imbalanced use of fertilizers. Application of fertilizers in a balanced amount with standard methods and at appropriate time keeping in mind the soil nutrient status, soil moisture, crop type, and crop growth stage can increase yield by 25-75 percent.

Plant protection:

Insects, pests, disease, and weeds cause yield reduction up to 20 percent or more during pre-and post-harvest periods. The farmers are bound to use pesticides in order to keep the population of insects and pests under control. The application of pesticides increased from 665 tons in 1990 to 78,133 tons in 2003. Lack of quality control, high cost, adulteration, timely unavailability, and lack of education, and the use of faulty equipment by untrained labor are the major constraints responsible for the ineffectiveness of pesticides.

Modern technology:

Non-application of modern technology is contributing to low yield than the world average. Infusion of modern management practices in the farm sector to boost productivity is important to enable farmers to move farm subsistence to market-driven farming that requires changes in crop selection, cultivation, harvesting, marketing, transportation, and adoption of new technologies.

Adoption of new technology is also important to convert farmers’ work into capital. Subsistence farmers produce food to sustain them only and new technology will enable them to produce surplus. New technology would give farmers more choice and help them plan cultivation in a demand rather than supply-driven environment. Modern techniques for plant protection measures are required for effective control of diseases, insects, and pests to avoid crop.

Miscellaneous:

Dwindling land and water resources, stagnation in the yield of major crops, ill-trained farm labor, poor infrastructure, wasteful irrigation methods, traditional farming techniques, lopsided marketing system, and above all implications are the main issues and challenges facing an outdated agriculture sector.

The industry is dependent on agriculture, so enhancing the agriculture means the improvement of the raw materials, therefore the improvement of most of the industries over the entire country.

A.2. Manage and increase the sources of clean water

Egypt has been suffering from severe water scarcity in recent years. Uneven water distribution, misuse of water resources, and inefficient irrigation techniques are some of the major factors playing havoc with water security in the country. Egypt has only 20 cubic meters per person of internal renewable freshwater resources, and as a result, the country relies heavily on the Nile River for its main source of water. The River Nile is the backbone of Egypt's industrial and agricultural sector and is the primary source of drinking water for the population.

Rising populations and rapid economic development in the countries of the Nile Basin, pollution, and environmental degradation are decreasing water availability in the country. Egypt is facing an annual water deficit of around 7 billion cubic meters. In fact, United Nations is already warning that Egypt could run out of water by the year 2025.

Causes:

Population Explosion:

Egypt's population is mushrooming at an alarming rate and has increased by 41 percent since the early 1990s. Recent reports by the government suggest that around 4,700 newborns are added to the population every week, and future projections say that the population will grow from its current total of 92 million to 110 million by the year 2025. The rapid population increase multiplies the stress on Egypt's water supply due to more water requirements for domestic consumption and increased use of irrigation water to meet higher food demands.

Inefficient Irrigation:

Egypt receives less than 80 mm of rainfall a year, and only 6 percent of the country is arable and agricultural land, with the rest being desert. This leads to excessive watering and the use of wasteful irrigation techniques such as flood irrigation [an outdated method of irrigation where gallons of water are pumped over the crops as. A further decrease in water supply would lead to a decline in arable land available for agriculture, and with agriculture being the biggest employer of youth in Egypt, water scarcity could lead to increased unemployment levels. Inefficient irrigation is shown in figure 1.

Figure 1

Irrigation by flooding

https://www.usgs.gov/special-topic/water-science-school/science/irrigation-methods-furrow-or-flood-irrigation

Pollution:

The pollution of the river Nile is an issue that has been regularly underestimated. With so many people relying on the Nile for drinking, agricultural, and municipal use, the quality of that water should be of pivotal importance. The reality is that the water of the Nile is being polluted by municipal waste and industrial waste, with many recorded incidents of leakage of wastewater, the dumping of dead animal carcasses, and the release of chemical and hazardous industrial waste into the river.

B. Problem to be solved

Our grand challenge is to Increase the industrial and agricultural bases of Egypt and Manage and increase the sources of clean water. These challenges are highly dependent on the poor Irrigation systems and the misuse of materials, which leads to spending huge costs to irrigate and provide the small areas with nutrients. the fundamental issue facing agriculture is the declining supply of water. As the population continues to increase so does demand for food, but the amount of water available to produce that food does not increase. There is competition over the water in the rivers. The primary significant contributor to the issue is wasteful water. Out of the wide range of water system frameworks utilized, surface frameworks are both the most well-known and the most un-productive strategies of irrigation. In surge flow systems plants retain 75% of the water and in traditional wrinkle frameworks, it is as low as 60%. More effective water system ways are less inclined to be utilized.

The second part of the problem for agricultural water use is that the types of crops grown are not always suitable to the climate and environment. Government subsidies exacerbate this problem since they encourage the growth of water-consuming crops in areas where such farming is not economical and is inefficient.

B.1. What will happen if we solved this problem?

- Decrease the consumption of clean water by substituting the poor irrigation systems.
- Decrease the costs of agricultural activities by managing the use of materials as water and nutrients.
- Improve the economic conditions of the country.
- increasing the cost-efficiency ratio.

B.2. What will happen if we didn’t manage to solve this problem?

- The poor irrigation system will still be wasting water.

- leaching of nitrogen and other micronutrients, and wastes time.
- Crop nitrogen needs, fertilizer costs, and nitrogen losses to groundwater.
- The excessive cost of wasted water and fertilizer will affect the cost-efficiency ratio negatively.

C. Research

Information about the problem and the solution had to be made, to collect enough data and knowledge that can lead the project into the optimum road of success.

C.1. Research about the problem:

From the research about improving the agriculture and maintain the water resources the following have been concluded:

The main problem facing agriculture is the declining supply of water. As the population continues to increase so does demand for food, but the amount of water available to produce that food does not increase. There is competition over the water in the rivers.

The first major part of the problem is inefficient irrigation. Out of the many different irrigation systems used, surface systems are both the most common and the least efficient methods of irrigation. In surge flow systems plants absorb 75% of the water and in conventional furrow systems, it is as low as 60%. More efficient irrigation ways are less likely to be used.

The second part of the problem for agricultural water use is that the types of crops grown are not always suitable to the climate and environment. Government subsidies exacerbate this problem since they encourage the growth of water-consuming crops in areas where such farming is not economical and is inefficient.

Besides, lower water prices for farmers encourage wasteful usage. A specific example is the federally built Central Valley Project in California. This is a mass of infrastructure which supplies water for irrigation at prices between $7.14 and $56.73 per acre-foot. Since these prices are so low, by September 2005 agricultural users had only repaid 18% of the initial investment. Thus, they are receiving the water at an unrealistic price which does not promote conservativeness as much as it could. So, this means the farmers that get affected psychologically and make mistakes even though they may have good circumstances.

C.2. Research about the solution: From the research, it is concluded that several factors are related to a working solution:

Management by algorithms: Fixed main plan and algorism is one of the keys of a successful solution to the mentioned problem; because when a system is controlled by an algorism for example artificial intelligence, it will always pay attention to the rules it has and it will not be manipulated resulting in wasting of water or usage of excesses fertilizers.

Strength of the database: A well-established and connected database will connect all of the valuables which other resulting in a well-made decision. While a weak connection between the database will not consider all of the variables which could lead to systematic problems with agriculture. An example of the weak connected database is a farmer that does not use temperature as a variable for watering his plants, resulting in miscalculating the water needs of the plants.

Low maintenance: Some systems require a lot of people working on it while others do not. Surely, those systems that have low maintenance would be easier to establish under most of the circumstances than others.

D. Other Solutions Already Tried

The project's main objective is to increase the industrial and agricultural bases of Egypt and managing the sources of clean water using Artificial intelligence methods. Consequently, we have searched for prior solutions that may have been applied to solve these problems. Agriculture is turning to Artificial Intelligence technologies to help yield healthier crops, control pests, monitor soil, and growing conditions, organize data for farmers, help with the workload, and improve a wide range of agriculture-related tasks in the entire food supply chain

D.1. Soil and crop health monitoring system:

Type of soil and nutrition of soil plays an important factor in the type of crop is grown and the quality of the crop. Due to increasing, deforestation soil quality is degrading and it’s hard to determine the quality of the soil. A German-based tech start-up PEAT has developed an AI-based application called Plantix that can identify the nutrient deficiencies in soil including plant pests and diseases by which farmers can also get an idea to use fertilizer which helps to improve harvest quality. This app uses image recognition-based technology. The farmer can capture images of plants using smartphones. We can also see soil restoration techniques with tips and other solutions through short videos on this application. Similarly, Trace Genomics is another machine learning-based company that helps farmers to do a soil analysis to farmers. Such type of app helps farmers to monitor soil and crop health conditions and produce healthy crops with a higher level of productivity.

D.2. Solar pumps – a smarter way to irrigate

In western India and other parts of the country, heavily subsidized electricity to power water pumps have driven groundwater depletion. An unreliable electric grid, bankrupted utilities and power theft have contributed to the problem. Solar irrigation pumps have been promoted as a green energy solution, but subsidizing the cost of solar pumps can result in the same overexploitation of water resources. In Karnataka state in arid southwest India, the local electric company is required to buy back surplus solar power from farmers. The buyback policy, signed by Karnataka's governor last September is consistent with recommendations by scientists at the International Water Management Institute (IWMI) to treat solar power as a 'cash crop.' The rationale is that if farmers can make money by selling excess power, they then will have an economic incentive to irrigate their crops, thus helping to conserve groundwater and energy use.

D.3. FarmBot

founded in 2011. This company has taken precision farming to a different level by enabling environment-conscious people with precision farming technology to grow crops at their place. The product, FarmBot comes for $4000 and helps the owner to do end-to-end farming all by himself. Ranging from seed plantation to weed detection and soil testing to the watering of plants, everything is taken care of by this physical bot using an open-source software system.

But we found that all these solutions are not effective enough to solve this grand challenge due to the subsequent reasons.

Though Artificial Intelligence offers vast opportunities for application in agriculture, there still exists a lack of familiarity with high-tech machine learning solutions in farms across most parts of the world. Exposure of farming to external factors like weather conditions, soil conditions, and the presence of pests is quite a lot. So, what might look like a good solution while planning during the start of harvesting, may not be an optimal one because of changes in external parameters. AI systems also need a lot of data to train machines and to make precise predictions. In the case of vast agricultural land, though spatial data can be gathered easily, temporal data is hard to get. For example, most of the crop-specific data can be obtained only once a year when the crops are growing. Since the data infrastructure takes time to mature, it requires a significant amount of time to build a robust machine learning model. This is one reason why AI sees a lot of use in agronomic products such as seeds, fertilizer, pesticides, and so on rather than in-field precision solutions.

II. *Present and justify a problem and solution requirements*

A. Design requirements

For the prototype to be successful, it must be able to meet some requirements which will assist in solving our grand challenge which is to increase the industrial and agricultural bases of Egypt and manage and increase the sources of clean water. These challenges are highly dependent on the poor irrigation systems and the misuse of materials, which leads to spending huge costs to irrigate and provide the small areas with nutrients. Therefore, we identified some specifications that could lead to a successful solution such as the applicability of the solution, the low cost, the artificial intelligence that depends on the accuracy of the predictions, and the level of artificial intelligence.

A.1. First- Intelligence:

The intelligence of the project depends on the level of artificial intelligence, and the accuracy of predictions.

A.1.1. level of artificial intelligence:

Each AI could be classified into three levels. Each level of AI has specific characteristics and Knowledge representation. Level one has characteristics and abilities as perception, attention, basic learning, discrimination, classification, and memory. Level two has characteristics as spatial, numeric, social. Level three has characteristics as planning, problem-solving, language, and reasoning. According to this date, we can classify our solution intelligence.

A.1.2. Accuracy of predictions:

One of the most important aspects of AI is its predictability. Each AI system should have the ability to predict new values and outcomes according to its inputs, which made AI different from traditional programming. This predictability is determined concerning the training set. The accuracy of these predictions could be measured by comparing the results with the real-life impact of these results.

A.2. Second- Applicability:

Numbers aren't everything. The theoretical planning of the project is not more valuable than the actual representation in real life and level of project implementation. Therefore, we will measure the applicability of our project by testing the AI mechanism, the mechanism of the hardware sensors, and the accuracy of Its measurements in the real life.

In our capstone project, we are working on measuring all factors that affect plant growth as the humidity of the soil, the length of the plant, and the ambient temperature.

Humidity of soil: the humidity will measure by a soil moisture sensor with specific ranges.

Ambient temperature: the ambient temperature will measure by the contactless temperature sensor.

Length of the plant: the length will measure by the ultrasonic sensor, which will be done by certain mechanisms to define the length of the plant remotely.

A.3.Third- Low Cost :

Cost is one of the major problems in modern irrigation systems. Surface irrigation systems are characterized by low cost and low efficiency compared to other systems and with increasing cost the efficiency increases. Therefore, we are working to maintain a low-cost solution, with high efficiency in distributing water and nutrients, compared to other conventional solutions.

B. Selection of solution

After the process of collecting data about the problem and identifying the prior solutions, we were able to choose the suitable solution for using an AI to Increase the industrial, agricultural bases of Egypt and to manage the sources of clean water. The solution will depend mainly on two aspects:

1- Managing water rate for the plant
2- Handling the nutrients rate of the plant.

As the solution generally aims for a well-structured specialized plan for every single plant to obtain the maximum efficiency of the system and with reducing the cost.

The first part of the irrigation system which is managing the rate of water in the plant, will depend on many variables that will be managed by the artificial intelligence part. The first variable is the type of plant which will be given by the user to the AI system. The second one is the humidity of the plant which will be handled by the AI by controlling the concentration of water vapor present in the air by using the soil humidity sensor. The third aspect in the irrigation part is the temperature, as the water rate will slightly increase as the temperature increases. And the AI part will control the temperature by a Contact-less Infrared Temperature Sensor that measures the surface temperature of an object without touching it, depending on the emitted IR waves of the target, and measures the average temperature over a particular area.

The second part is managing the nutrients rate that the plant needs. The AI system will be able to do this by following 2 methods, the first one is to determine the type of plant and the second by determining the height of the plant by an ultrasonic sensor, which is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound. Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has traveled to and from the target). And this will be useful for the AI as it will be able to determine precisely the accurate nutrients rate for the plant, as the height of the plant increases, the nutrients rate will decrease.

C. Selection of prototype:

The prototype is divided into three portions as in Figure 2:-

1- Inputs
2- Outputs
3- AI part and managing the data.

First (Inputs):

There are three inputs:-

Frist input is the height of the plant. This is done by using an ultrasonic module that measures the distances and the servo motor.

Second input is mearing the soil moisture. Moisture is measured using the soil moisture sensor that gives an indication of soil moisture from 0 to 100.

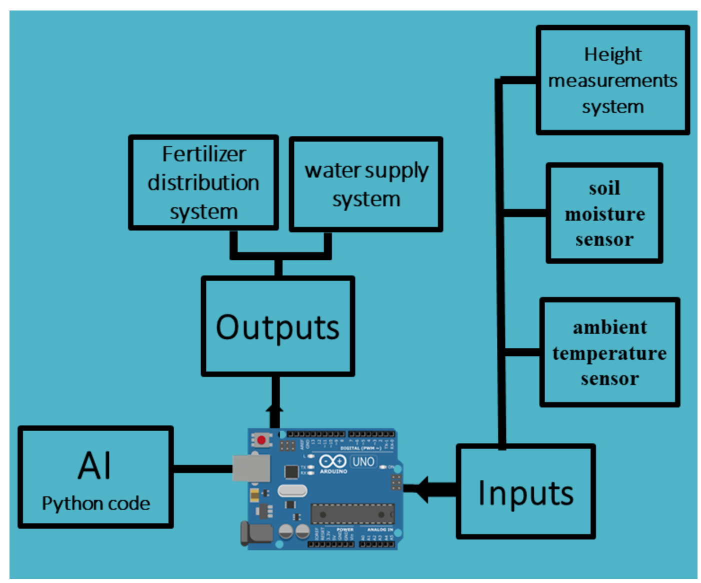


Figure 2

Illustration of the prototype

Third input is measuring ambient temperature. This was done by using the contactless temperature sensor that is able to measure the temperature of objects and air.

Second (Outputs):

Frist output is supplying plants with water. The amount of water a plant needs depends on the ambient temperature and soil moisture. Therefore, the water pump is controlled by Arduino code and AI python to determine the amount of water to be pumped according to the inputs of the contactless temperature sensor and the soil moisture sensor.

Second output is providing the plants with fertilizers. The amount of nutrients a plant needs depends on the height of the plant. Therefore, the nutrients pump is controlled by Arduino code and AI python to determine the amount of nutrients be pumped according to the ultrasonic system readings.

Third (AI part and managing the data):

Frist part is the AI part, which is a python code that predicts the amount of nutrients and water a plant needs as in figure 3.

The code starts with adding the main libraires as NumPy, pandas and TensorFlow to be able of using Artificial neural network. Then, adding the dataset collected before to train the AI. The AI code finds best function that could predict the graphs of (temperature Vs moisture) and (height Vs amount of nutrients) according to the collected dataset and the activation function used is sigmoid function, which is a mathematical function having a characteristic "S"-shaped curve or sigmoid curve.

```python
import pandas as pd
import numpy as np
# Make numpy values easier to read.
np.set_printoptions(precision=3, suppress=True)
import tensorflow as tf
from tensorflow.keras import layers
from tensorflow.keras.layers.experimental import preprocessing

abalone_train = pd.read_csv(
    "dataset.csv",
    names=["Temperature", "Moisture"])

abalone_train.head()

abalone_features = abalone_train.copy()
abalone_labels = abalone_features.pop('Moisture')
abalone_features = np.array(abalone_features)
abalone_features
abalone_model = tf.keras.Sequential([
  layers.Dense(64, activation="sigmoid"),
  layers.Dense(1, activation="sigmoid")
])
optimizer = tf.keras.optimizers.SGD(learning_rate=0.1)
abalone_model.compile(loss="MSE",
                      optimizer=optimizer)

abalone_model.fit(abalone_features, abalone_labels, epochs=10000)

data = np.array([[68]])
predictions = abalone_model.predict(data)
print(predictions)
```

Figure 3

Python code used in the project

Second part is the Arduino part, which is the Arduino code for controlling the sensors and pumps. This code receives sensor readings and sends them to the AI portion and receives predictions from the AI about the amount of water and nutrients needed. Then the Arduino code starts taking action according to these predictions.

how the prototype will meet the design requirements you have chosen?

With this approach our selected design requirements are met according to the following:

- Low Cost: is accomplished by using very specialized plans to meet the water and nutritional needs of the plants, which leads to decrement of the cost and the increment of the efficiency.
- Intelligence: this was accomplished in two aspects, first the accuracy of predictions, as the project predicted values shall be very near to the wanted values so we accomplish the best efficiency. Second, the intelligence level is determined according to a scale from 1 to 3, where any level from 1 to 3 is considered artificial intelligence and ours shall be 1.
- Applicability: this system shall be applicable in the aspects of finances since it has a well determined and chosen cost-efficiency ratio and shall be applicable in the terms of the ease of use as it is an automated system.

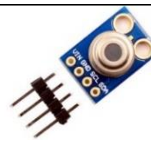
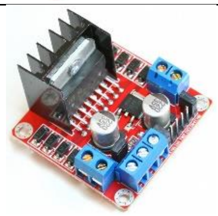
Mentioning how the project will be able to meet the design requirements these are the ways they can be tested:

- Cost: is tested by calculating the cost of our system and then comparing this cost with other smart systems cost.
- Intelligence: this was tested in two aspects, first the accuracy of predictions, as the project predicted values will be compared with the real needed values. Second, the intelligence level is determined according to a scale from 1 to 3, where any level from 1 to 3 is considered artificial intelligence and ours shall be 1 and it shall meet that expectation.
- Applicability: the applicability will be examined when the project is finished by evaluating how easy the project is used and how effective are the mechanisms that are used by the system.

III. Constructing and Testing a Prototype

A. Materials and Method

A.1. Materials

Item	Picture	Quantity	usage	cost	Source
Mini water pump		2	To conduct water and nutrients for the plants	120	Radio Masr Electronics Store
Micro Servo Motor		1	Is a part of the length measuring system.	40	Radio Masr Electronics Store
Arduino UNO		1	Microcontroller to control the system.	100	Radio Masr Electronics Store
ultrasonic sensor hc-sr04		1	To measure the length of the plants.	35	Radio Masr Electronics Store
Contactless temperature sensor		1	To measure the ambient temperature.	150	RAM Electronics Store
L298 Motor driver module		1	To prevent the direct connection between Arduino and the pumps and control the pumps by external power source.	50	Radio Masr Electronics Store
Batteries		2	To supply the pumps with the required power	60	Radio Masr Electronics Store
Soil moisture sensor		1	To measure the humidity of the soil.	40	Radio Masr Electronics Store
Programming (Python, Arduino IDE)			The main code that manages how the system works.	00	

A.2. Safety Precautions:

For making any project, we must follow some safety rules such as:

• Being careful when dealing with any devices or electronic modules like Soil moisture sensor and water pumps.

• Handle electricity with care, especially with water, in order not to harm ourselves.

• Constructing the prototype under the supervision of an expert observer.

A.3. Methods

A.3.1. First (constructing the prototype): The prototype is divided into five parts:-

The first part is measuring the height of the plant. This was done by using an ultrasonic module that measures the distances and the servo motor. This system is installed with a certain mechanism for movement as in figure 4.

Figure 4

The setup of the ultrasonic sensor

The second part is mearing the soil moisture. Moisture is measured using the soil moisture sensor that indicates soil moisture from 0 to 100. It is installed as shown in figure 5.

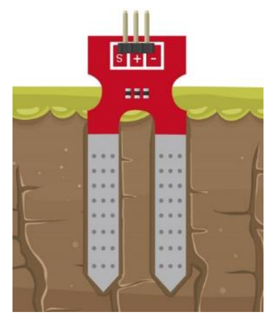


Figure 5

The setup of the soil moisture sensor

The third part is measuring ambient temperature. This was done by using the contactless temperature sensor that is able to measure the temperature of objects and air.

Forth part is supplying plants with water. The amount of water a plant needs depends on the ambient temperature and soil moisture. Therefore, the water pump is installed and controlled by Arduino code and AI python to determine the amount of water to be pumped according to the readings of the contactless temperature sensor and the soil moisture sensor.

Fifth part providing the plants with fertilizers. The amount of nutrients a plant needs depends on the height of the plant. Therefore, the nutrients pump is installed and controlled by Arduino code and AI python to determine the amount of nutrients be pumped according to the ultrasonic system readings.

A.3.2. Second (programming stage): After building the prototype and installing those five parts with the Arduino in one system, it comes to the programming stage which is divided into two parts.

The first is the AI part, which is a python code that predicts the amount of nutrients and water a plant need. This python code is made by an artificial neural network to generate predictions using the dataset collected. The AI code in figure 5 is made by libraries like NumPy, pandas, and TensorFlow. The AI code finds the best function that could predict the graphs of temperature Vs moisture and height Vs amount of nutrients according to the used dataset and the activation function used is the sigmoid function.

The second part is the Arduino part, which is the Arduino code for controlling the sensors and pumps. This code receives sensor readings and sends them to the AI department and receives predictions from the AI about the amount of water and nutrients needed. Then the Arduino code starts taking action according to these predictions.

B. Test Plan

B.1. Intelligence:

First, the accuracy of predictions:

Objective: Measure how accurate is the system.

Procedures:

•The system will be put in a certain temperature that requires a certain amount of water

•The system would be left to measure the temperature and provide the water

•The amount of water provided by the system is compared with the amount of water that would be provided if the plant was irrigated in an ordinary way

Second, Level of intelligence

Objective: Determine the level of intelligence of the project.

Procedures:

observations are made to see at which level does the system fits. As, level one is characterized by perception, basic learning, classification, and memory. Level two spatial, numeric, social. Level three planning, problem-solving, and reasoning.

B.2. Applicability:

Objective: Ensure that mechanisms used by the system, to take the measurements as heigh, can be applied in real life.

Procedures:

•The mechanisms are observed to see how well will it perform, especially when used in real-life simulating situations.

•Measurements are taken as the height and compared with the real height to see the performance of the system in real life.
Observation: the measurements by system and the actual measurements are very close.

B.3. Low cost:
Objective: Achieving low cost which is our design requirements
Procedures:
•calculating the cost of each part and the cost of developing.
•comparing the final cost with the cost of other smart systems.
Observation: the total cost of the prototype is relativity cheap to the cost of other smart systems.

C. Data Collection

After the test plan, we started to collect the data and to measure the results of the prototype, and compare it with the design requirements.

For the accuracy of measurements, we followed a method consists of 2 phases before collecting the data as shown in the following figure 6.

C.1. AI Intelligence:

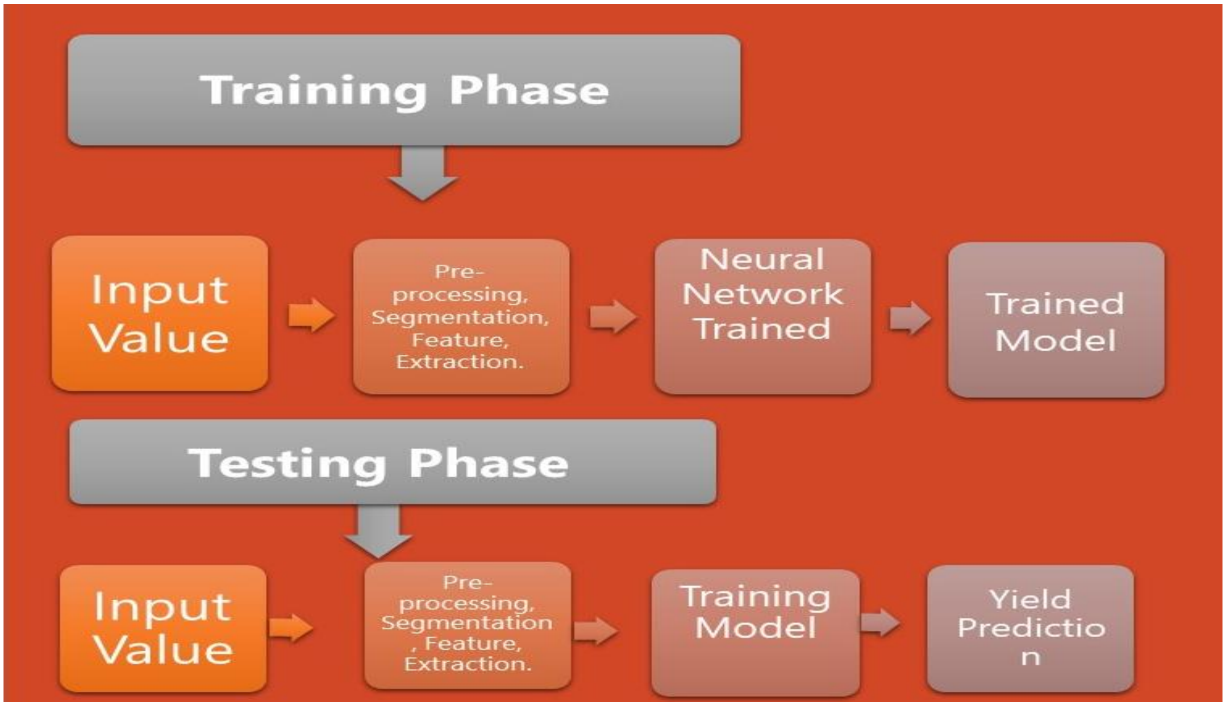


Figure 6

The procedures used before collecting the data

Level of Intelligence:-

After defining the properties of the prototype - attention, basic learning, and memory, it turns out that the prototype includes properties that differ from traditional programming. According to these characteristics, the prototype is AI and its intelligence is classified as level 1 or basic AI.

Accuracy of predictions:-

After constructing the whole prototype and testing the AI, the accuracy results were not 100% accurate. The AI had a slight deviation in results as in chart(2)

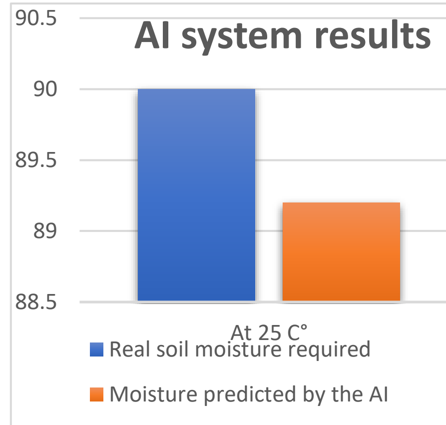


Chart 2

Comparison between the predictions of the system and the real values

At a temperature of 25 C °, the real soil moisture required for the plant was 90. The AI predicted that soil moisture should be 89.2.

C.2. Applicability:

After measuring the heights of two plants by the AI system and compare these measurements with the real heights, it turns out that the system works and measures the heights effectively as in chart(3)

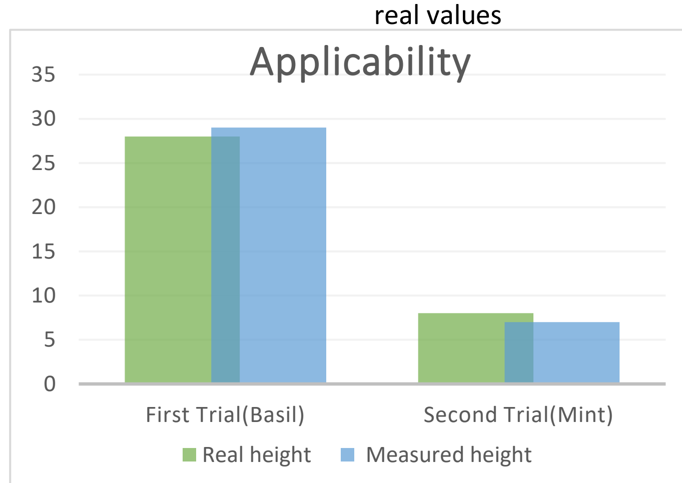


Chart 3

Comparison between the values measured by the system and those measured by the ruler

First trial: the real height for the first plant(Basil) was 28 and the measured height by the AI system was 29.

Second trial: the real height for the second plant(Mint) was 8 and the measured height by the AI system was 7.

C.3. Low Cost:

After Calculating the cost of the system, it turns out that the system and the cost of development is around 1,150 EGP. the other smart system is called “Low-Cost Smart Irrigation Control System” and costs 20,000 Indian rupees, equivalent to 4,295 EGP as in chart(4).

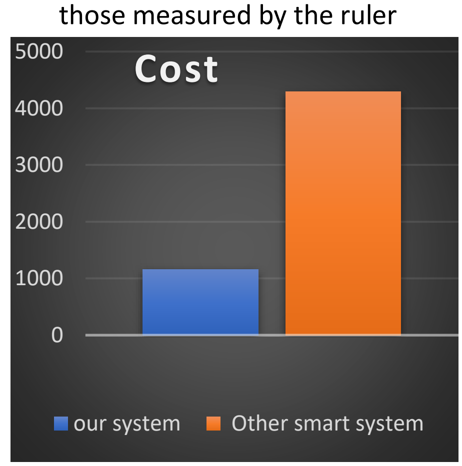


Chart 4

Comparison between the cost of this system and other systems

C.4. Measurement Tools:

The elements that served as measurement tools for the project are listed below according to each measured design requirement:

• Level of Intelligence: The categories of artificial intelligence that are in figure 7, served as a measurement tool for the level of intelligence.

• Accuracy of prediction: The database Oregon state education was a reference to compare the prediction of the system

• Applicability: A ruler was used to compare the real measurements with those measured by the system.

IV. Evaluation, Reflection, Recommendations

A. Analysis and Discussion

A.1. Analysis

As every project must have its aim, two main problems, or grand challenges, were chosen to work on; Increase the industrial and agricultural bases of Egypt, and Manage and increase the sources of clean water.

These challenges are highly dependent on the poor Irrigation systems and the misuse of materials, which leads to spending huge costs and wasting gallons of water to irrigate and provide the small areas with nutrients. Another fundamental issue facing agriculture is the declining supply of water. As the population continues to increase so does demand for food, but the amount of water available to produce that food does not increase. There is competition over the water in the rivers.

These issues require a new irrigation system that can regulate water and nutrient use, and prevent wastage of these materials. This solution will contribute to the water shortage problem by saving wasted water and save the huge costs that are being paid in wasted water and nutrients. This solution is an AI-based irrigation system that has a specialized plan with an amount of water and nutrients required for each plant. Such a solution will not be implemented unless certain requirements are met to ensure that the main problem is successfully resolved without causing other problems to arise.

A.1.1. AI intelligence:

The intelligence of the AI depends on the level of artificial intelligence, and the accuracy of predictions.

level of artificial intelligence: In order to define if the code is traditional programming or an AI programming, and what's the level of this AI. It should have some characteristics that differentiate between traditional programming, AI programming, and advanced AI programming. As shown in the results, the prototype has characteristics and abilities as attention, basic learning, and memory. These characteristics are according to figure 7.

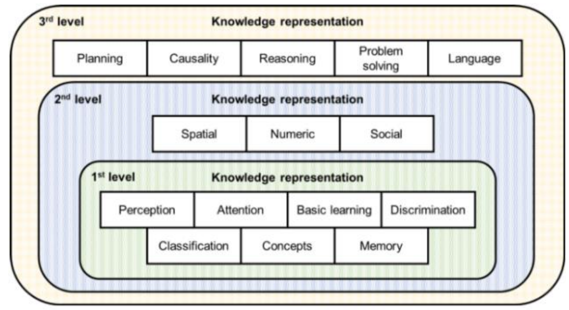


Figure 7

The levels of artificial intelligence.

The concept of "attention" is related to sensors when environmental factors such as temperature and height change. The AI realizes this and adjusts its outputs according to this change. The concept of "basic learning, and memory" is achieved when the artificial intelligence system changes its output according to the new data set saved in its memory, and with each new added value to the data set, the artificial intelligence learns it and comes with a more accurate equation.

Accuracy of predictions: One of the most important aspects of AI is its predictability. Each AI system should have the ability to predict new values and outcomes according to its inputs, which made AI different from traditional programming. This predictability is determined for the training set. To measure the accuracy of predictions, a certain temperature is chosen. The AI predicted that the soil moisture should be 89.2. the real soil moisture required for the plant was 90, which is close to 89.2. The difference between the two measurements is 0.8. According to the following rule:-

$$\boldsymbol{error\ percentage = \frac{measured\ error}{acaul\ measurment} * 100}$$

The prediction error percentage of AI is around 0.9%, which means that the AI system is 99.1% accurate in its results. These findings demonstrate that the AI system has achieved high prediction accuracy.

A.1.2. Low Cost:

Choosing the right materials, mechanisms and development has aided in fulfilling the design requirement of the low cost. As it is usually known that smart systems especially those which are artificially intelligent are pretty expensive, so working on the materials and the tools used to construct the prototype the cost of this project is cheaper. Thus, after calculating the charge of the system, it appears that the system and the cost of development is around 1,150 EGP, while another smart system called “Low-Cost Smart Irrigation Control System” is costing 20,000 Indian rupees, equivalent to 4,295 EGP as in chart(4), therefore, the Indian system is around 4 times as expensive as this intelligent system.

A.1.3. Applicability:

Another major design requirement is Applicability. The mechanisms used in the system have to be applicable in real life, not just theoretical planning. The most complicated mechanism in the prototype is the ultrasonic part for measuring the height of the plant. This part works by mini servo motor and ultrasonic. They are installed as in figure 8.

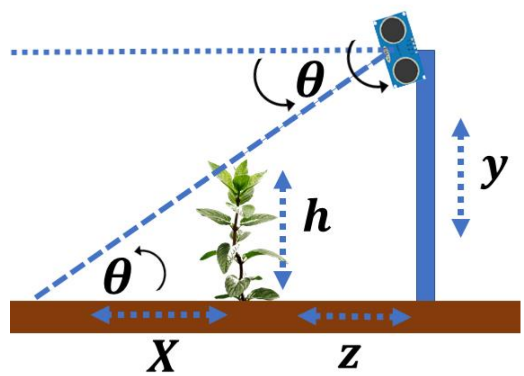


Figure 8

The mechanism used in measuring the height.

$\boldsymbol{h}$ is the height of the plant. $\boldsymbol{y}$ is the wand that holds the ultrasound sensor. $\boldsymbol{z}$ is the distance between the stick and the plant. $\boldsymbol{X}$ is the distance from the plant and the end of the hypothetical triangle.
$\boldsymbol{\theta}$ is the angle between the horizontal axis and the hypotonus of the hypothetical triangle? Therefore, $\boldsymbol{y}$ and $\boldsymbol{z}$ are two known constants and $\boldsymbol{\theta}$ is known by the servo motor that could define its angel.

$$\tan\ \theta = \frac{y}{x+z} = \frac{h}{x} \qquad\qquad h = y - z\tan\ \theta$$

According to these equations, the AI system measures the $\boldsymbol{h}$, which is the height of the plant. After defining the mechanism of measuring height, it had to be tested to ensure that it is applicable. The results indicated that the height measurement mechanism worked and gives approximately the same measurement with a slight difference which is 1 cm in the trials conducted.

A.1.4. Why was the artificial neural network (ANN) chosen?

In the world of artificial intelligence, choosing the right function is the key to the most accurate predictions. Finding the best activation function that can generate accurate prediction was not easy.

First, a linear regression function was chosen. A linear regression function is a linear approach between two variables by fitting a linear equation to represent data as in chart 5 Therefore, the linear equation will not always be the best equation to predicate accurate values as in chart 5. In this chart, the points themselves take the shape of carve, which made each linear approach is far from the right values. This was the issue with the Linear regression approach.

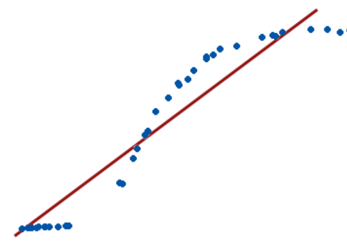


Chart 5

After the Linear regression approach Failed, the artificial neural network (ANN) was chosen. The ANN opened the opportunity of using a non-linear approach to represent the data as in chart 6, which results in more accurate predictions. the used activation function used is a sigmoid function and Its formula is

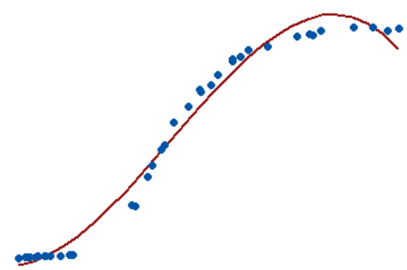


Chart 6

$$s(x) = \frac{1}{1+e^{-x}}$$

This function was the best activation function to represent the collected dataset and generate predictions with an accuracy of 99.1%.

A.2. Conclusion

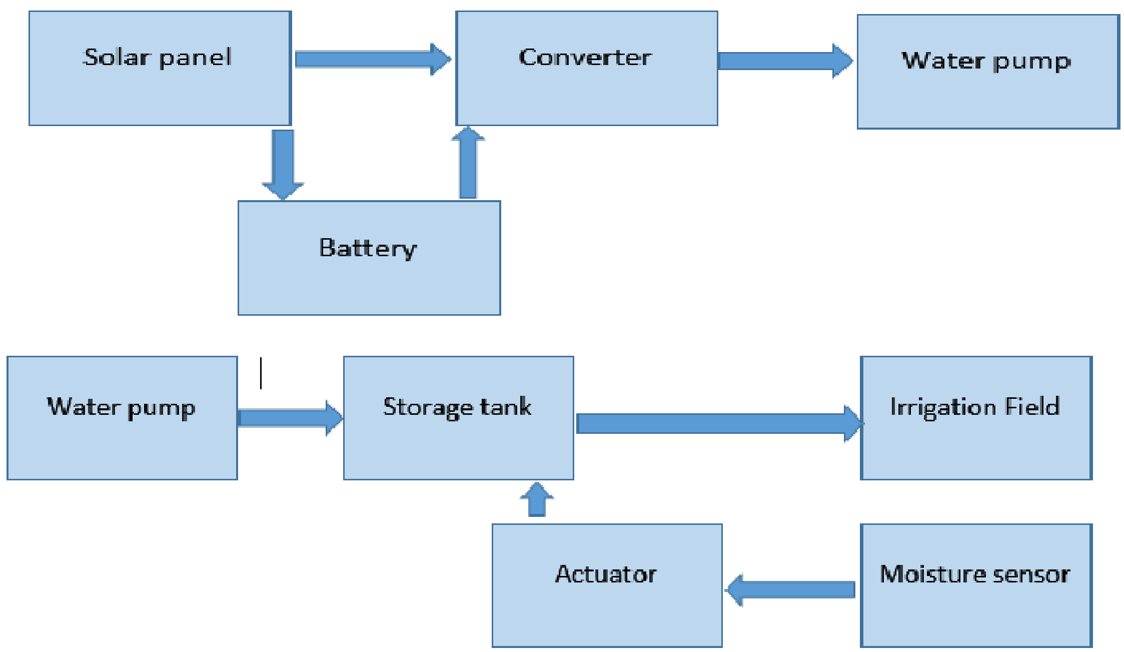
Depending on the data from the results and analysis, we were able to demonstrate how the results achieved the chosen design requirements. The AI has shown a high level of accuracy according to the Ultra-Sonic test, and it was determined that our system can be run with level 1 AI. In addition to the elevated applicability of each part in the irrigation system, and its low cost comparing to the other systems like the "low-cost smart irrigation system", as our automated Irrigation system is less expensive than the Indian system by 3300 EGP. So, our vision to use a novel technique that allows extending the profits of the agriculture system and decreasing the cost and human efforts has been achieved according to these design requirements and analysis. Nevertheless, comparing with the existing irrigation systems, the automated irrigation system was more efficient and beneficial on the large scale. As we found in our searches that the recently used smart irrigation systems lacked the connection between the farmers and the use of AI equipment, and the cost-efficiency didn't reach the desired objective. So, we carefully avoided this by enhancing the intelligence of the AI and sampling the phases to be easily used by the farmers, which reached us to solve the challenge of the high demand for smart systems and AI-based techniques in yield prediction and agriculture.

B. Recommendation

There is always an open chance for creative modifications on any project. So, for future work by any other team in this area, and further developments on the Automated Irrigation system, we suggest that they could put efforts into the project in these ways:

- Trying to minimize the cost of system deployment.

- Working on saving energy by adding a system of solar cells that produce renewable energy for the AI irrigation system, which will also result in decreasing the cost of using energy, but the cost must be considered while adding the solar cells by classifying its type and cost-efficiency ratio as illustrated in figure 9.



"https://www.researchgate.net/publication/281685755_Solar_Powered_Smart_Irrigation_System"

Figure 9

Illustration of the recommendations.

- Training of uneducated and non-techno-savvy farmers is still challenging, so working on making the AI system unpretentious will avoid any errors or flaws in the progression of the system.

C. Learning Outcomes

Some learning outcomes have been pretty helpful for this project as the following:

BI.3.01: The mechanism of neurons and their similarity to the neural network. Layers like input, output, and hidden layers are similar to human neurons. This similarity helped the team understand the idea of neural networks.

CH.3.04: helped learn about the mathematical analysis of quantitative data.

PH.3.01: helped understand infrared contactless temperature sensor mechanism.

PH.3.03: helped understand the waves and ultrasonic sensor mechanism, and building mechanisms of measuring the height of the plants according to this understanding.

PH.3.08: helped understand the mechanisms of reception of waves used as in ultrasonic and infrared temperature sensors.

ST.3.01: The distribution that was observed in the AI system.

ST.3.02: Helped learn about the scatter plot, linear regression, and the differences between data representation methods.

MA.3.01: Helped learn about the rate of change of a variable with other variables and how to measure the derivative of certain volume with respect to time, which is used in measuring the amount of water and nutrients pumped per minute.

MA.3.02: Sketch the graph and/or find the equation of the function.

PH.2.13: The information about electronics and electronic components helped us while building the hardware part of the irrigation intelligent system.

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