Automated Irrigation

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Abstract

The world is going towards a more specialized version of everything. Hearing about a farmer that wakes up early to water his plants is something normal to hear. But this project purpose is to change this normal, going towards a better, specialized, and intelligent version. Furthermore, Using Artificial intelligence (AI) the project is solving two important grand challenges of Egypt: Increasing the industrial and agricultural bases of Egypt, which acts as a challenge because agriculture is the base and the raw material of mostly everything, and Managing and increasing the sources of clean water, which is causing a challenge because of the increment of water demand as the population increases.

The solution is a system that measures the height, moisture, and temperature, then integrates this data knowing the plant type to provide a very specialized plan of water and nutrients to the plants. This way the project is able to fulfill the design requirements which are: intelligence in the aspect of accuracy and level of intelligence, the applicability, and the low cost.

Moreover, to construct a prototype for this project Arduino UNO and AI python coding are used as a microprocessor and AI department to integrate the data, then it was trained to collect the data and set a best fit equation for it to be able to predict the desired outputs.

Testing and observing the system had given some findings which are: specialized irrigation and fertilizing have lower cost where it is quarter the cost of other smart irrigation system. The system is on level one of intelligence so it was able to preform the required tasks, and the system was pretty accurate. Moreover, the used mechanisms in the project helped it to applicable.

In conclusion,The AI system is much better than the ordinary ways of irrigation and fertilizing, where a specialized plan gives better cost, more intelligence and even lower effort.

Introduction

Through specialization, artificial intelligence and integration, this system provides a solution to two important grand challenges of Egypt: Increasing the industrial and agricultural bases of Egypt which is a multi-dimensional challenge where irrigation, technology, nutrients application, and miscellaneous are aspects for the challenge, as the demand for food and raw materials is increasing, which is leading to increment over the last decades as shown in chart 1 where the crops are growing in tons more and more as the time passes. Managing and increasing the sources of clean water which is an issue because of population explosion, inefficient irrigation, and population, where the population is increasing exponentially putting pressure on the demand of water. Moreover, it is solving this semester challenge through applying artificial intelligence.

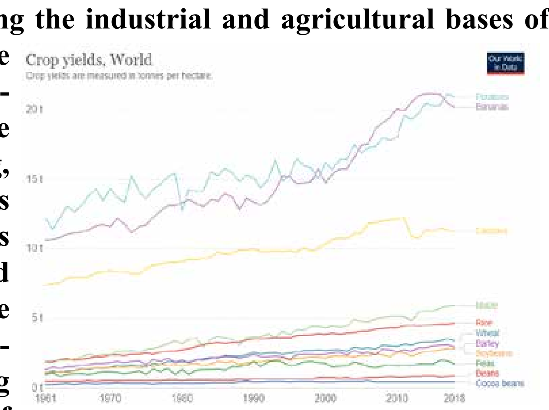

Chart 1

Since agriculture is an important element in human life as it is the source of everything, . Thus, prior solutions have tried to increase the agricultural base such as: Soil and crop health monitoring system, a system that monitor the pest and the health of the crops, which have a strength as it notifies the farmer by the health of the crop but it has a weakness as it does not take actions towards it.

Solar pumps is a another solution that are using a very expensive solar panels to create energy for water pumps in the agricultural field which has an advantage in being eco-friendly but it is very expensive to use.

So learning from other's weakness, This system had to fulfill three design requirements: intelligence in the aspect of accuracy, the system intelligence has to pretty accurate in predicting the needed values,level of intelligence,as the system has to have some kind of intelligence in order to preform, the applicability, the system has to be able to be used in real life, and the low cost. Thus the project will be intelligent enough to integrate the data to irrigate and fertilize the crop on its own, choosing the right mechanism to make it applicable and the right materials to have low cost.

Materials


Figure 1
Water pump


Figure 2
Micro Servo Motor

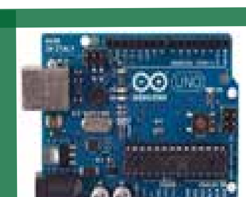
Figure 3
Arduino uno


Figure 4
Ultrasonic sensor


Figure 5
Arduino ID Software


Figure 6
Con tactless temperature sensor

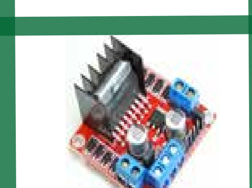
Figure 7
L298 Motor deriver module


Figure 8
Batteries


Figure 9
Soil moisture sensor


Figure 10
Python Software

Method

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

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 set up as figure 11.

Second is measuring the soil moisture. Moisture is measured using the soil moisture sensor that gives an indication of soil moisture from 0 to 100 and installed as figure 12.

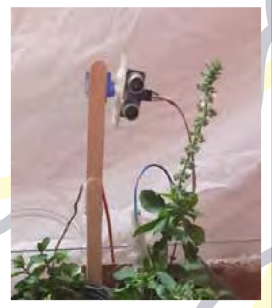
Figure 11

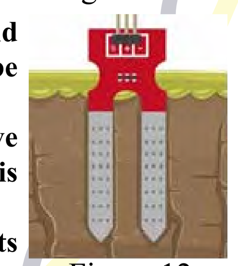
Figure 12

Third part is measuring ambient temperature. This was done by using the contactless temperature sensor.

Forth part is supplying plants with water. 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.

Fifth part providing the plants with fertilizers. 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.

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.

First part is the AI part, which is a python code that predicts the amount of nutrients and water a plant need. It is made by Artificial neural network. The AI code in figure 13 made by libraries as numpy, pandas and tensorflow. The AI code finds best function.The AI code finds the best function that can predict the graphs of temperature Vs moisture and height Vs amount of nutrients according to used dataset and the activation function used is sigmoid function.


Figure 13

Second part is the Arduino part, where the Arduino code is controlling the sensors and pumps according to the AI department.

Test Plan:

•Intelligence: First, the accuracy of predictions:

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

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

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

Second, Level of intelligence that is observed 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.

•Applicability: The mechanisms used by the system are observed to see how well will it preform, especially when used in real-life simulating situations

•Low cost: Achieving low cost which is our design requirements

Procedures:

1)Calculating the cost of each part and the cost of developing.

2)Comparing the final cost with the cost of other smart systems.

Results

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

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)

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

Chart 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)

First trial: the real height for the first plant(Basil) was 28 ± 0.1 and the measured height by the AI system was 29 ± 0.1.

Second trial: the real height for the second plant(Mint) was 8 ± 0.1 and the measured height by the AI system was 7 ± 0.1.

Intelligence : Accuracy

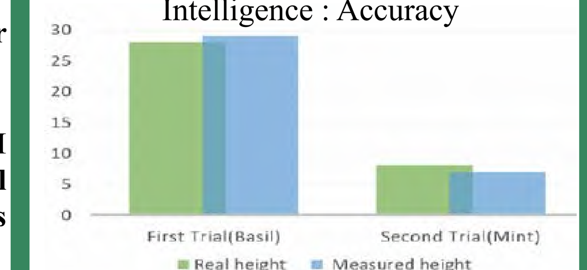

Chart 3
Applicability

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 called "Low Cost Smart Irrigation Control System" and costs 20,000 Indian rupees, equivalent to 4,295 EGP as in chart(4)

Chart 4
Cost

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 food, but the amount of water available to produce that food does not increase. 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 in order to ensure that the main problem is successfully resolved without causing other problems to arise as the following:

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 a traditional programming or an AI programming, and what's the level of this AI. It should have some characteristics as in figure 14 that differentiate between the traditional programming, the AI programming, and the advanced AI programming. As shown in results, the prototype has characteristics and abilities as attention, basic learning, and memory.

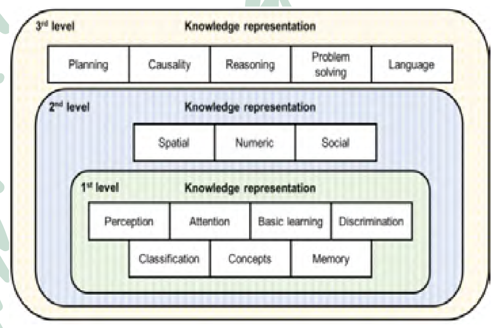

Figure 14

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 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 the 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 with respect to the training set. In purpose to measure the accuracy of predictions, certain temperature is chosen. The AI predicted that the soil moisture should be 89.2. the real soil moisture required for plant was 90, which is to close to 89.2. The difference between the two measurements is 0.8. According to equation (1) 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.

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

Equation 1

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.

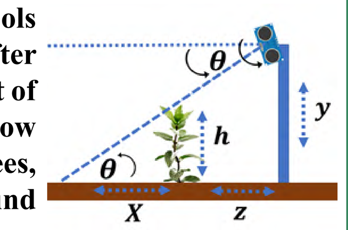

Figure 15

Another major design requirement is Applicability. The mechanisms used in the system has to be applicable in real life not just a theoretical planning. The most complicated mechanism in the prototype is ultrasonic part for measuring the height of the plant. This part works by mini servo motor and ultrasonic. They are installed as in figure (15).

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

Equation 2

θ is the angle between the horizontal axis and the hypotenuse of the hypothetical triangle. Therefore, y and z are two known constants and θ is known by the servo motor that could define its angel. According to equation 2 and equation 3, the AI system measures the 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 slight difference which is 1 cm ± 0.1.

$$h = y - z\tan^{-1}\theta$$

Equation 3

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.

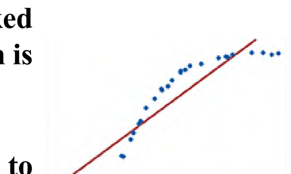
Chart 5

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 figure, 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.

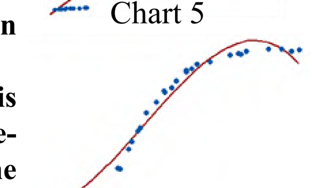
Chart 6

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 function is equation 4.

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

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

Equation 4

Learning Transfer

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

BI.3.01: The mechanism of neurons and its 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 network.

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 rate of change of a variable with other variable 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.

Conclusions

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 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 using of AI equipment's, 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 demanding of smart systems and an AI- based techniques in yield prediction and agriculture

Recommendation

For further developments on the Automated Irrigation system, we will need to raise the cost which will decrease the cost-efficiency ratio. So, for additional efforts on the project:

- Trying to minimize the cost of system deployment.

- Working on saving the 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.

- 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.

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