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Research Article

Design and development of soil-less plant health monitoring system using deep learning

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Abstract

Increasing population of the planet leads to concern about meeting the need for food for every living entity on the planet for the future, and there should be some smart ways in which people can produce their own food.The intelligent and stable hydroponic farming system is a new method of soilfree farming and will help users track their hydroponic farm / garden plant health remotely without relying on time and location.The smart and stable Hydroponic farming device is a new way of soil-free farming and it will help users track their hydroponic farm / garden remotely without relying on time and location, which will provide maximum food production in a limited space with good food quality irrespective of the use of large quantities of pesticides for plants.The current challenges with traditional farming include poor water levels of land in many regions of the country, poor seed quality, increased use of fertilizers and biocides, and many more. The hydroponic farming method would ensure the health of consumers such as humans and animals with nutrient-rich benefits and costeffective compared with traditional farming.The cultivation of food without compromising all factors. The system will help individuals to grow plants without compromising ongoing work, time and space, and they can monitor them from anywhere.

Keywords: *Deep learning,Nutrients,Monitoring system,soilless Farming,statistical measures.*

Introduction

Soil-less farming is a method for plant growth without the use of soil in an artificial environment. Water-supplied nutrients and better growing conditions to improve performance[1].By nature,soil-less agriculture is a method of growing plants in a solution based on water, which is rich in nutrients. Alternatively, the root system is protected by an inert medium such as perlite, rockwool, clay pellets, peat moss or vermiculite.One of the key requirement principles in soil and soil-less structures for each vegetable production is to To deliver all the nutrients a plant desires.Several elements are essential for plant growth and production called Macro-elements and Micro-elements:carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, manganese, iron, zinc, boron, copper, molybdenum and chlorine. Among the elements mentioned above, there is a category according to their origin: organic, C, H, O and minerals; broken down into macro-nutrients, N, P, K, Ca, Mg, S, and micro-nutrients, Mn, Fe, B, Zn, Cu, Mo, Ni, Cl (Malavolta, 2006).In soil-less farming plants nutrition absorption is usually proportional to the concentration of nutrients in the solution near the roots and is highly influenced by environmental factors such as salinity, oxygenation, temperature, pH and nutrient conductivity, light intensity,photo-period and air humidity(Furlani et al.,1999)[2].

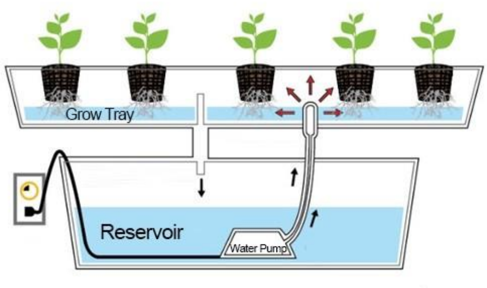

Fig. 1. Basic NFT system (Source:https://www.nosoilsolutions.com/)

The above fig.1 depicts basic structure for NFT type soilless system.The system is mainly divided into parts including Reservoir with nutrients needed for growing plants and grow tray for holding plants appropriately in nutrients with properly managed levels to assure that roots are able to absorb nutrients from reservoirs.We targeted NFT model of hydroponic gardening in this study, which is also referred to as nutrient film technique.Soil-less agriculture can be applied in a variety of ways, but the NFT method is most common and convenient.In this section, we understand the different ways of growing plants hydroponically, including the benefits and drawbacks of each along with an abundance of useful, generic hydroponic knowledge.

A. Types of Soil-less farming system

- NFT system:
- Wick system
- Ebb and Flow system
- Deep water culture
- Drip system
- Aeroponics

1)

2) Nutrient Film Technique(NFT) system: The nutrient solution is injected into channels with NFT systems that can carry varying quantities of plants, nutrient solution flows through the channel over the roots of the plant that hang out, and back into the reservoir.NFT system works best with plants that have a small root system,like leafy greens.

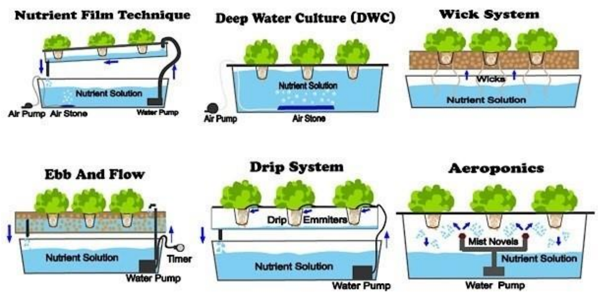

Fig. 2. Types of soil-less farming system(https://www.nosoilsolutions.com/)

3) Wick system: The wick system is the easiest type system requiring no electricity, pumps or aerators.its simply known as passive system means there was no need for electricity.

4) Ebb and Flow system: This system can also be referred to as a flood and drain system for which plants are placed in a large growing medium that is flooded with a solution of nutrients until it reaches a certain point.

5) Deep water culture(DWC): With this system the plant roots are suspended in the solution of nutrient water and air is supplied directly to the roots with an air stone or diffuser. This works best with plants for massive roots or once they produce abundance of fruit.

6) Drip system: With this system, the nutrient solution is pumped directly to the plant base through tubes, and can be either circulating or non-circulating.

7) Aeroponics: The plants are suspended in the air in this system and the nutrient solution is sprinkled over the roots.

Literature Survey

The human population is growing rapidly and in the next 30 years it will reach about 9 billion. In order to meet the rising demand for food, agricultural production will need to increase over 70 percent[3].Because the earth's resources are already strained, it is important to find an alternative methods of food production that do not involve further land degradation and loss of biodiversity. The goal is to develop an improved and cost-efficient hydroponic system that can test horizontal or vertical hydroponic tubing systems and experiment with low-energy (LED) light systems that draw upon solar energy. Growing leafy greens and herbs has become a new and exciting field in the agricultural industry. Already, companies like Lecetra, Green Earth, and Vertical Harvest Hydroponics have been making important strides in advancing new agro-technology. The majority of these companies use a vertical growing system to maximize their plant yield and each shipping container can produce between 25,000 to 50,000 heads of leafy greens per year [4]. They have also championed the use of LED's as a light source, and all elements within their container systems can be measured and changed remotely. In trying to determine an estimated cost, a variety of information was considered. Nicholas was able to construct a small, hydroponic garden of lettuce for under Dollar 300 as a student at California Polytechnic State University. This small system was only able to grow 20 plants at a time. On the other end of the spectrum, purchasing a fully operational shipping container from Freight Farms would cost Dollar 76,000 plus Dollar 13,000 per year in operational costs [4][5].Although the cost is significantly higher, one farmer can grow up to 4500 plants per container at a time and the technology to manage the system has already been created and installed.This project was able to produce a similar type of system as these pioneering companies by using deep learning techniques and an array of images to measure the features of plants at different levels of the plants and their need for nutrient solution for same.The data the machine compiles will send to the internet, where it can be accessed remotely.The popularity of AI and deep learning has allowed many makers to easily create the system which will be flexible, programmable hardware platform with a fairly standard techniques that can interact with the world around it by using its programmable inputs and outputs.Current and past members of the ReEnergize project have performed research and experiments on a motorized vehicle to be placed inside the shipping container in order to take readings [6]. They built and tested two different, robotic vehicles that could be programmed to move via line sensor technology. A hoisting mechanism on top of the vehicle was meant to allow sensors to reach different vertical heights where additional readings could be taken.

Overview of soil-less farming system

The system is designed and implemented with Image Recognition for a smart hydroponics farm. It is observed that the crops monitored by using automatic control were better than the crops raised by manual control as an outcome of which the evaluation of good and quality crops has been achieved, thus empowering farmers to achieve good economic and ecological benefits and significant importance for the development of modern crops. It is proposed that the data collection process must be longer in order to efficiently improve the system because greater data would have produced better data analytics performance. Our system will be trained with a large dataset of plant images with parameters of classification being: healthy, malnourished, malnourished, dried, etc. This dataset will help us train the model to try to test our algorithm accurately. The proposed system approach is as follows:

- For initial feedback to the device, multiple live / current images of plants are recorded.
- These images are then given as an input to the evaluation module
- The current plant condition will be graded and calculated based on the inputs and different classification parameters listed above.
- If the system determines that the plant is healthy, no further action needs to be taken.

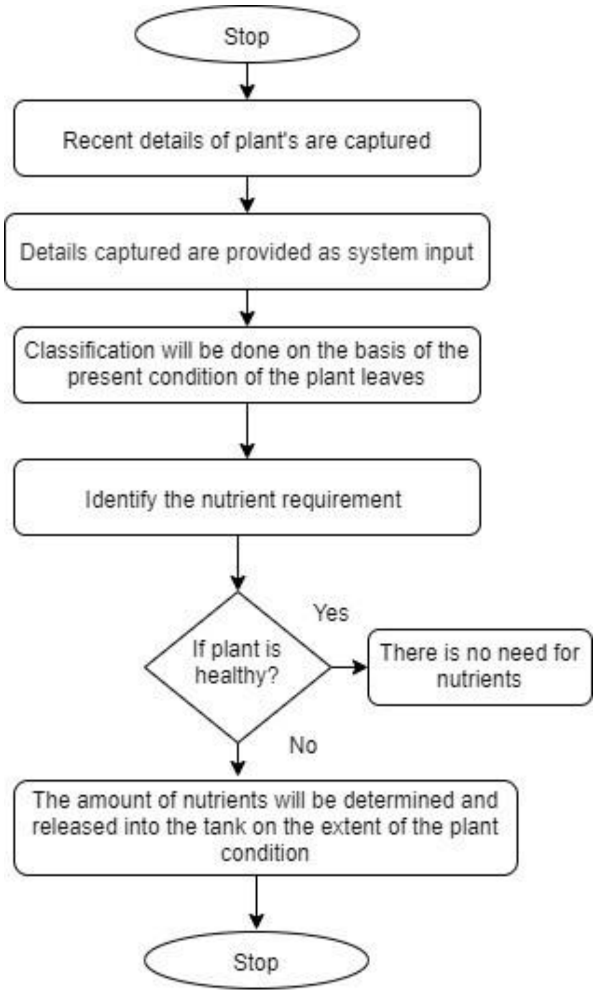

Fig. 3. System flowchart

- If the system tags the plant as infected / diseased / malnourished, a proprietary built algorithm will determine the amount of nutrition required depending on the condition of the plant being evaluated by the system. Figure 3 shows the flow and operation of the system.

A. Construction of soil-less farming

In order to make the hydroponics farm autonomous, this research will use a deep learning method to discover data transmitted over the network.The algorithm implements an input-based procedure in which the information interpreted is based on current inputs and makes the correct decisions about the output. The decisions are transmitted to a server after processing the data where the user is provided with relative notification to monitor and control the device.

1) Working of Neural Network:: The Provided Figure illustrates the operation of a single output neural network with a basic multiple X functions.The input layer holds the X features used to input the hidden layer that is the next layer in the neural network.Each layer in the neural network has a certain number of neurons, which are essentially functions for performing the task of taking the input and making some calculations with the input by applying the activation function provided and then providing the output as an input to the next neuron in the next layer again.

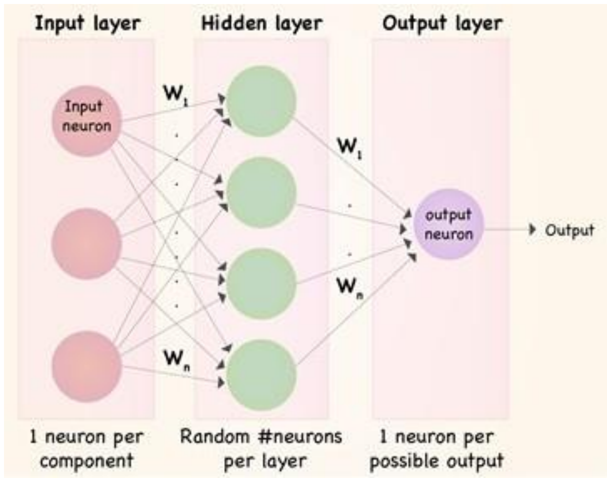

Fig. 4. Neural Network Architecture(Image source:Google)

Thus some forms of activation mechanism are used in the process. The ones we used are the sigmoid function in equation (1) at the last layer and also the Tanh function in equation (2) in the rest layer.The Sigmoid Function as:

$s(x) = ex/(ex+1)$ (1)

The Tanh function as:

$f(x) = tanh(x) = (ex-e-x)/(ex+e-x)$ (2)

Also the last layer is called output layer.In the above image Wn is also said to be the nth weight added to the input function per neuron to determine where the output will be mapped.For the given number of epochs, the neural network then runs correcting its error from the input data and checking whether the predicted value is correct or not, and then resolving itself by predicting a value closer to the actual value thus reducing the loss value.

2) Soil-less plant setup: The soil-less farming setup for tomato plant is done with the help of following factors:

- Nutrient solution tub (reservoir).
- Underwater fountain / water pump.
- Tubing for flow of water from the pump to the through tubes of the N.F.T.
- Growing tubes for growing in the plants (also called a channel).
- small baskets and growing media to begin seedlings in.
- Return device (channels) to direct the nutrient solution used back to the tank

B. Dataset

The dataset used in the study is Tomato Plant Leaf Dataset. The dataset is available on plant-village dataset for various plants. The dataset contains 24,000 images with 10 categories All images are with 256 x 256 dimension in RGB.Images are classified into categories like Healthy, Bacterial Spot, Early Blight, Late Blight, Curl virus, Spider Mites, Leaf mold,yellow leaf curly virus,Septoria leaf spot,target spot etc.

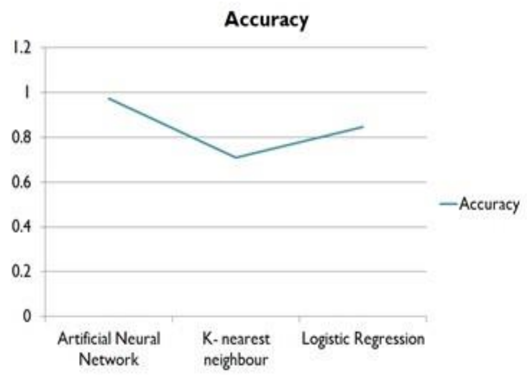

Fig. 5. Comparison among classification algorithms with x axis: Algorithms/y axis: Accuracy

Results and discussion

The proposed system would result in different accuracy when implemented using different neural network algorithms and classification algorithms. The results of how effectively the device can assess the plant's current condition are based on ease of implementation and accuracy metrics established.The test was carried out on a small set of data, which can be further adapted and increased for better accuracy.The below Table 1 provides details about comparative analysis among different algorithms and achieved respective accuracy on dataset .

Table I Comparative Analysis for Accuracy

Algorithms	Comparison Among Algorithms		
	ANN	*KNN*	*Logistic regression*
Accuracy	0.904	0.690	0.894

Some of the major Classification algorithms were used in this study to determine the condition of hydroponic plants, such as Artificial Neural Network(ANN), K-nearest neighbor, Logistic regression.Figure 5 shows the comparative analysis given for the same among all which results in better classification with maximum accuracy.

Conclusion

Some of the key Classification algorithms were used in this study to evaluate the condition of hydroponic plants, such as relu, Sigmoid, tanh, Naive Bayes, K-Nearest algorithm and also the Logistic Regression algorithm to decide the state of the current plant.Classification techniques were included in the research, because it enables us to classify the plant into different categories. The dataset used has been compiled from the references below, while some are generated by us in our own validated hydroponic system.The system enables us to monitor and grow good grade vegetables in our own backyard or house balconies while being safe and free from harmful pesticides and fertilizers towards a healthy lifestyle.

Future Work

In the future, the system can be further extended by using Artificial Intelligence hybridization and fuzzification to achieve better results by coordinating other plant factors such as development and plant root quality.

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