ARTIFICIAL INTELLIGENCE BASED HYDROPONICS: A REVIEW

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Abstract:

In order to keep up with the demands of the ever-increasing population, farmers and owners of commercial plantations are forced to resort to using harmful chemicals to produce more, but this affects the consumers in the long run. Hydroponics is the method of growing plants directly in a water medium, eliminating the use of soil, thereby taking away the high maintenance costs and side effects mentioned earlier. This paper covers several different metrics for managing plant growth using Internet of Things (IoT) and our objective is to derive a machine learning algorithm to optimize the values of all the metrics. Our future project focuses on devising a hydroponics system that is robust and has increased efficiency.

INTRODUCTION

The soil is the most abundantly available medium for plant growth. However, the conventional agricultural method of using soil takes up a lot of space, involves a lot of labor and large volumes of water. Considering these drawbacks, the concept of soil-less culture was introduced. Hydroponics is the method of growing plants or vegetables without soil, but using mineral nutrient solutions mixed with water.

Since land is quickly being urbanized and cities are expanding at a rapid rate this helps justify the study and implementation of hydroponic growing techniques because it does not require soil. Along with the many uses for hydroponic on earth, we can even begin seeing the usefulness of hydroponics in future space travel. Hydroponically grown plants have their roots dipped in nutrient solutions mixed with water. This allows them to get the required nutrients much easier compared to plants grown by the conventional method. The nutrient solution is the food source for the plants and hence the factors in it need to be controlled. There will be many devices interconnected to create such a system. The main component used is a microcontroller, since Arduino is the most accessible, it was chosen for the purpose of this project.

The disadvantages of hydroponic systems are that it is expensive - it involves the cost of all the equipment you need—containers, pumps, lights, nutrients, and so on. There's also a certain amount of toil involved as hydroponics is more scientific and the plants are much more under your control, they need to be checked constantly to ensure they grow in favorable conditions.

The system consists of three parts:

1. The first part is the detection sensors which include air temperature, humidity, PH, water temperature, and ultrasonic sensors.
2. The second part covers the control system which is implemented using IoT. The role of the control system is to manage plant growth by monitoring the values from the sensors.
3. The last part focuses on selecting a machine learning algorithm to quantify plant growth. Artificial Neural Network (ANN) was considered for the same since it gives the best results when dealing with complex systems.

In the future, we aim at improving the existing hydroponics systems to make them more efficient.

II. SYSTEM OVERVIEW

A. ARCHITECTURE

The general concept of the proposed IoT system is shown in Fig.1. The grow tent that was used in this research is a 50x40x20 cm box. The system consists of sensors, microcontroller, and a communication module. The system monitors and controls several parameters in the grow tent: temperature, water pH, and light intensity. The sensors used are DHT11 (temperature humidity sensor), pH sensor, and LDR (light intensity sensor). The micro-controller is programmed using Arduino IDE. For online monitoring, sensors (pH, temperature, and light) data will be transmitted to the server and displayed on a website.

B. DESIGN

The prototype is a physical structure, which contains a plant enclosure and an electronics enclosure. The plant enclosure contains plants, each in its own net pot with clay beads. In addition, there are LED light strips above, and an air pump that feeds into the bucket and aerates the water. The electronics enclosure contains the Arduino UNO microcontroller, which controls the power to the water pumps and light, and it also monitors the control circuit as described in Fig. 1

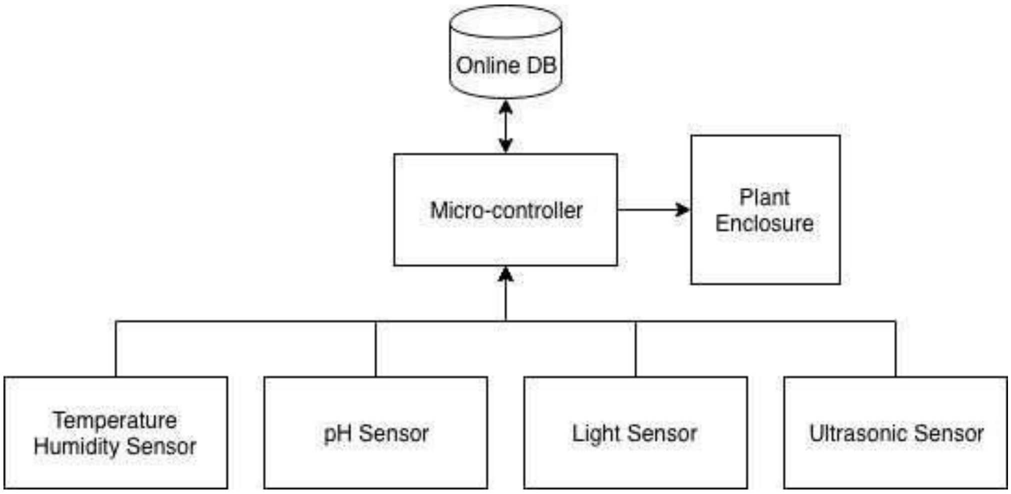

Fig.1 System Architecture

The following are specifications for the design components:

1. The Arduino UNO is the main microcontroller of the system which receives data from the sensors and passes it onto other parts. The server is used for processing and then feeding all the values into the database.
2. pH control is a necessity in hydroponic systems as pH changes constantly with plant growth. The PH Sensor measures the hydrogen-ion concentration in a solution, indicating acidity or alkalinity of water-based solutions. The user can set limits on the pH levels and if the pH level fluctuates outside of the predefined levels, a warning message will be sent to the user.
3. The controller must also be able to measure the moisture and air temperature. For this, a DHT11 sensor is used since it has good temperature accuracy.
4. The light sensor is used to obtain light intensity measurements. It works based on a principle that it will generate a current which will be proportional to the received light intensity. This sensor is needed to be connected to a signal conditioning circuit before connected to micro-controller.
5. The Ultrasonic Sensor is a device that can measure the distance from an object by using sound waves. It measures distance by sending out a sound wave and listens for that sound wave to bounce back. After the sound wave bounces back, it can calculate the distance between the sensor and the object.

III. WORKING

There are two essential parts, software, and hardware. The hardware is composed of an Arduino Uno microcontroller and multiple sensors, while the software running the algorithm is a server. The centralized server back-end is composed of three separate subsystems. An HTTP server designed to handle and serve requests to plants and users, a SQL database used to store plant and user information, and the learning algorithm, designed to process database information and provide the HTTP server meaningful control states for individual plant systems.

An important assumption is made, that for any plant, there is an optimal set of parameters that will maximize a health metric or an objective function which measures the health of the plant. Growing a plant requires the following steps:

1. Startup Phase
(a) Transplant young plants to clay beads filled pots.
(b) Mix nutrient solution.
(c) Add the control system to monitor the different parameters.

2. Run Phase
(a) Upload plant data based on one of many possible plant health metrics.

(b) The server runs an iteration of the learning algorithm.
(c) Each sensor in the control system will query the server for parameters on a set interval.

After constructing the prototype system, the viability of optimizing the health of a plant was tested using a machine learning algorithm.

A. IoT

The system starts by reading the temperature and humidity from DHT11 (Temperature and Humidity Sensor).

After that, it is checked if the values lie within the threshold range. If the values aren't within the threshold, the system will turn on the water pump to water the setup and reduce the temperature. When the value comes into the range of the threshold, the system will turn off the water pump. The data or value read is shown on the webpage.

The system then checks for pH value, and the solenoid valve adjusts the pH till it reaches the set threshold. All the data collected in this part can be viewed via the web application

B. MACHINE LEARNING

Artificial intelligence (AI) has developed to such a degree that it can lead to an intelligent control system capable of self-examination. The combined information from different sensors, through AI methodologies such as neural networks (NNs), can lead to quality classification of isolated information derived from specific sensors.

Objective for implementation of Machine Learning is development of a system for design and training parameterization of NNs that would be more sophisticated than the trial-and-error methodology usually used for these tasks.

The NN approach to the application was chosen mainly because of the specific nature of hydroponics, and also for its simplicity. Hydroponic systems are highly non-linear because of the non-linearity of the biological processes involved. Thus, estimation methods would not be suitable, mainly because of their high computational demands in the cases of non-linear systems. [11] In addition, precise analytical models of the hydroponic system do not exist; thus, estimation methods become unacceptable. From the pattern recognition methods, NNs were considered to be the most appropriate because it was decided that the autonomy that AI gives to this approach is preferable to some arbitrary selection of complicated mathematical tools that other pattern recognition techniques would require.

The NN model has to identify the dynamics of the physical process, i.e., the hydroponic system. More specifically, the model is used mostly for prediction of state variables rather than simulation.

All the data is collected during the whole growing period of the plant, i. e. the 25 days that the plants are in the ponds of the hydroponic system.

This information consisted of measurements of the pH, the electrical conductivity (EC) and the temperature of the nutrient solution, as well as the temperature, the relative humidity and the light intensity. Also, additional information was given by the control signals of the controlled parameter, that is the pH.

Artificial Neural Networks (NN) are systems or models that try to estimate or approximate a function from sample data. Modeling using a NN consists of three main steps:

1. Selection of the NN architecture,
2. Training of the NN, and
3. Testing of the trained NN.

IV. Development of ANN Model

In this study, the ANN model consisted of three layers: an input layer, a hidden layer, and an output layer. Between the input and output layer, at least one hidden layer exists. The number of hidden layers and the number of units in the hidden layer is determined by trials.

The structure of the nets used in the study is shown in Fig. 2. Inputs are time series data of 5 environmental conditions (solar radiation, inside temperature, inside humidity, nutrient water temperature, and CO2 concentration). Outputs are the amount of water and nutrient supply to hydroponic plants.

The input/output data are obtained every hour. To calculate the water and nutrient supply at the time T o'clock, M hours of data (from T o'clock to T-M+1 o'clock) are used, where M is a span of input data. Therefore, the number of input units is 5xM and the number of output units is two. Several cases of constant M is tested and the optimal number is determined empirically.

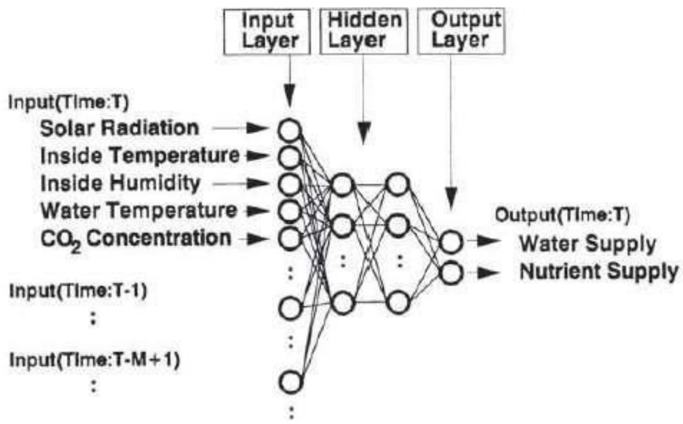

Fig. 2 Neural nets for the identification of water and nutrient supply.

Back propagation was used as the learning method, which is composed of two procedures: feed forward and back propagation weight training.

The data samples were divided into two data sets, a training data set and a testing data set. A training data set was used for training the neural network, and a testing data set was used for evaluating the accuracy of the identified model. This type of model validation is called "cross-validation".

The training process resulted in weight values of the ANN model for the relationship between input and output parameters. All variables were normalized between 0 and 1, using the fixed minimum and maximum values both in training and testing processes.

A. Training Results

The NN model was trained with experimental data collected during a whole growing period of the plants.

The training process has two parts:

1. Preliminary training process- investigates which network architecture trained with which algorithm gives the best results. This is achieved by training several candidate topologies (1-HL and 2-HL networks) with all training algorithms and the results are compared.
2. Basic training process- focuses on the training of already chosen network architecture with the algorithm that proved to be the best.

In this way, the best NN model is achieved. From the preliminary training, it was concluded that network architecture/algorithm combination that gave the best results was the 1-HL NN with 9 hidden nodes trained with the quasi-Newton algorithm.

The selected NN was further trained using the selected algorithm by the basic training process.

B. Testing Results

The testing process consisted of presenting new data to the trained NN model and comparing its output with the real system's output to observe its generalization capabilities and see how it performs in data that is different than what it was trained with.

V. Proposed Work

A successful development of an IoT platform with various sensors, imaging devices, and automation controls allows us to harvest data from the plants. Our end goal of creating a fully autonomous farm should also be able to predict crop yield, nutrient

usage, variance in growing conditions and water usage. The data harvested can be used to predict these major factors. For this purpose, we wish to integrate Machine Learning algorithms into our system. This would not only provide macro-level data and insights into the user's farm but also enable the hydroponic system to become fully autonomous and eliminate the need of human interference to keep the farm up and running under the most efficient conditions. A scalable, centralized system architecture would enable multiple farms to access data from other farms, thereby making the algorithms more efficient and accurate. Thus, we would be able to combine our IoT system with the recent advent of Machine Learning.

VI. Conclusion

After studying the drawbacks of the conventional farming methods, a soil-less culture is described and a system to control and monitor it has been presented. As one of the typical applications, more and more people realize the application of the IoT (Internet of Things) will bring broad development to the smart life.

As far as the machine learning model is concerned, the following conclusions can be derived:

1. The feed-forward neural network methodology was used as the main tool for the development of the model as it was capable of learning the physical and chemical interactions between the plants and the measured variables.
2. The one-hidden-layer architecture of neural networks proved to be more successful than the two hidden-layer one.
3. The basic training methodology used here was the Backpropagation Training Algorithm. Four different types of minimization algorithms were considered: steepest descent, quasi-Newton, conjugate gradient, and Levenberg–Marquardt algorithm. The quasi-newton backpropagation training algorithm with a fixed learning rate gave the best results.

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